

**The Association of Energy Intake with Body Mass in Children With and Without
Probable Developmental Coordination Disorder**

Mike Pryzbek, BSc (Honours)

**Submitted in partial fulfillment of requirement for the degree Master of Science in
Applied Health Science (Health Science)**

Supervisor: Dr. Jian Liu, PhD

**Faculty of Applied Health Sciences, Brock University
St. Catharines, Ontario**

Mike Pryzbek © October 2014

Abstract

Objective

To determine if there is an association between energy intake (EI) and overweight or obesity status (OWOB) in children with and without probable developmental coordination disorder (p-DCD).

Methods

1905 children were included. The Bruininks-Oseretsky Test of Motor Proficiency was used to assess p-DCD, body mass index for OWOB, and the Harvard Food Frequency Questionnaire for EI. Comparative tests and logistic regressions were performed.

Results

Reported EI was similar between p-DCD and non-DCD children among boys (2291 vs. 2281 kcal/day, $p=0.917$), but much lower in p-DCD compared to non-DCD girls (1745 vs. 2068 kcal/day, $p=0.007$). EI was negatively associated with OWOB in girls only (OR: 0.82 (0.68, 0.98)).

Conclusions

Girls with p-DCD have a lower reported EI compared to their non-DCD peers. EI is negatively associated with OWOB in girls with p-DCD. Future research is needed to assess longitudinally the potential impact of EI on OWOB in this population.

Acknowledgements

I would like to show my appreciation to the Faculty of Applied Health Sciences for their support and assistance in this program. I would particularly like to acknowledge my supervisor, Dr. Jian Liu for his numerous hours invested in me for this project during our weekly meetings as well as for his kindness and patience. I want to thank Dr. Paul LeBlanc for his helpful insight in the field of nutrition for my thesis. Further I thank Dr. Brent Faught and Dr. John Hay for there their outstanding knowledge in the areas of physical inactivity and motor proficiency. I want to thank the committee for helping me organizing my thesis and improve my writing skills. I am thankful for having Dr. Freudenheim as my external examiner. I am very happy to have such great support not only by my committee, but also my friends and family members.

\

Table of Contents

Chapter 1: Introduction

1.1 Preamble.....	7
1.2 Study Rationale.....	7
1.3 Objectives.....	8

Chapter 2: Review of Literature

2.1 Overweight or Obesity Status.....	9
2.1.1 Overweight or Obesity Status Background.....	9
2.1.2 Overweight or Obesity Status Measurement.....	10
2.1.3 Energy Intake	13
2.1.4 Physical Inactivity as a Proxy of Energy Expenditure.....	16
2.1.5 Maturity.....	19
2.1.6 Residence, Gender, and Body Mass.....	21
2.2 Probable Developmental Coordination Disorder.....	22
2.2.1 Developmental Coordination Disorder Background.....	22
2.2.2 Diagnosis.....	25
2.2.3 Prevalence.....	27
2.2.4 Potential Causes.....	27
2.2.5 Physical Inactivity and Developmental Coordination Disorder.....	28
2.2.6 Overweight or Obesity Status and Developmental Coordination Disorder.....	30
2.3 Summary: Linking p-DCD, Energy Intake, and Body Mass.....	32
2.4 Purpose, Objective, and Hypothesis.....	32

Chapter 3: Methodology

3.1 Study Population.....	34
3.2 Key Variables.....	35
3.2.1 Probable Developmental Coordination Disorder.....	35
3.2.2 Energy Intake.....	35
3.2.3 Overweight or Obesity Status.....	36
3.3 Covariates.....	37
3.3.1 Physical Inactivity.....	37
3.3.2 Demographic Data: Age, Gender, and Residence.....	37
3.3.3 Maturity Status.....	38
3.4 Statistical Analysis.....	39

Chapter 4: Results

4.1 Sample Characteristics Girls and Boys Separately	41
4.2 Correlation Results.....	42
4.3 Energy Intake in Children with and without p-DCD.....	44
4.4 Logistic Regression.....	45

Chapter 5: Discussion

5.1 p-DCD and Energy Intake.....	48
5.2 The Negative Association between Energy Intake and Overweight or Obesity Status.....	52
5.3 Study Limitations and Strengths.....	53
5.3.1 Cross-Sectional Design Limitation and Future Directions.....	53
5.3.2 Prevalence.....	53
5.3.3 Variable Measurement.....	54
5.3.4 Strengths.....	55
5.4 Future Directions.....	56
5.5 Conclusion.....	56

References

References.....	58
-----------------	----

Appendices

Appendix A: Demographic Summary Table with Exclusion of Missing Data and Outliers.....	87
Appendix B: Additional Energy Intake Results.....	88
Appendix C: Additional Logistic Regression Results.....	89
Appendix D: Descriptions of Studies Assessing the Association between energy intake and Body Mass.....	90
Appendix E: Pooled Analyses.....	94

List of Figures and Tables

Figure 2.4 Assessing the association between energy intake and body weight in children with p-DCD.....	33
Figure 3.1. Cleaning of the data.....	34
Table 4.1.1 Characteristics of girls aged 11-13 years old in the PHAST Study (2007) by p-DCD_status (N=964).....	41
Table 4.1.2. Characteristics of boys aged 11-13 years old in the PHAST Study (2007) by p-DCD_status (N=1011).....	41
Table 4.2.1 Pearson correlation matrix of motor proficiency, body mass index, waist circumference, physical inactivity, energy intake, and age-to-peak height velocity in girls.....	43
Table 4.2.2 Pearson correlation matrix of motor proficiency, body mass index, waist circumference, physical inactivity, energy intake, and age-to-peak height velocity in boys.....	44
Figure 4.3.1 Mean energy intake (kcal/day) in children with and without p-DCD after adjusting for physical inactivity, maturity status, and body mass (N=1683).....	45
Table 4.4.1 Logistic regression analyses of p-DCD and energy intake on overweight and obesity by gender.....	47

Chapter 1: Introduction

1.1 Preamble

Developmental coordination disorder (DCD) is neuro-developmental disorder featured by significant impairment in motor coordination (American Psychiatric Association, 1994; Kirby et al., 2008). Probable DCD (p-DCD) is a term used in several studies to classify DCD when the reference standards to diagnose the condition are not completely fulfilled. Children with DCD struggle with social and academic functioning as a consequence of their impaired motor development (American Psychiatric Association, 1994; Silman et al., 2011). The prevalence of DCD ranges between 1.8 and 9%, most commonly reported at 6% in children aged 9 to 11 years old (Lingam et al., 2009; American Psychiatric Association, 1994; Kadesjo & Gillberg, 1999; Cermak & Larkin, 2002; Gaines et al., 2008). The most definitive study in determining the prevalence of the disorder was done by Lingam et al. (2009). In this study the authors found the prevalence of DCD to be 3%. Due to motor difficulties in typical daily activities, these children tend to avoid participation in free and organized play in social games and sports (Cairney et al., 2005; Cairney, 2007; Silman et al., 2004). Their withdrawal from physical activity places them at an increased risk for obesity and other cardiovascular risk factors (Faught, et al., 2005).

1.2 Study Rationale

Together, energy expenditure and energy intake have a greater impact on the management of body mass, than energy expenditure alone (Rippe & Hess, 1998). Although it has been well documented that children with p-DCD are at a greater risk of

becoming overweight or obese partly because of physical inactivity (lower energy expenditure), researchers have not considered energy intake in this population. The imbalance of energy intake with energy expenditure is associated with adiposity (Jago, et al., 2004) and in time, over-eating leads to weight gain and obesity onset among adolescents (Sonneville et al., 2013). It is known that the increased inactivity is associated with increased body mass in children with p-DCD, however, energy intake has not been considered.

1.3 Objective

The objective of this study is to determine if there is an association between energy intake and body mass in children with and without p-DCD.

Chapter 2: Review of Literature

The following literature review will be organized by two pillars (sections) which are overweight or obesity status (OWOB) and p-DCD. Information uniquely pertaining to these variables will be branched off in subsections. Some subsections may overlap; however, their contribution to the pillars will be unique in this study. For example: physical inactivity is a subsection in both OWOB and p-DCD as it is related to them differently.

2.1 Overweight or Obesity Status

2.1.1 Overweight or Obesity Status Background

OWOB is important to study because this condition leads to major health problems later in life, such as cardiovascular diseases in adulthood (Lavie et al., 2009). Although there has not been a lot of research on the cardiovascular effects of obesity in children, childhood obesity is a very important issue since OWOB children have the risk factor for developing cardiovascular health problems later down the road (Bridger, 2009). OWOB is a condition characterized by excess body fat. The location of this fat is also important. Visceral compared to subcutaneous poses a greater risk of cardiovascular disease (Huang et al., 2001). In children, visceral fat has been positively associated with several metabolic issues, such as insulin insensitivity and low high-density lipoprotein cholesterol (Gower et al., 1999).

Childhood OWOB is important since the condition is likely to carry-over into adulthood. Over 80% of OWOB children and adolescents will remain OWOB as adults (Guo & Chumlea, 1999; Liu et al., 2012; Freedman et al., 2001). In a 22-year cohort study, Herman et al. (2009) found that the odds of being overweight in adulthood was 6.2 times greater (95% CI: 2.2, 17.2) in overweight compared to normal weight youth aged 7-18 years old. Further, the prevalence of OWOB is quite high in Canadian children. Researchers from Statistics Canada found that 32% of Canadian children aged 5-17 years old were either overweight or obese, and there was no gender difference in the prevalence (Roberts et al., 2012). These findings are important in terms of implementing preventative strategies against obesity for our youth.

2.1.2 Overweight or Obesity Status Measurement

Body mass index (BMI) is a common proxy of OWOB. It is calculated using weight and height ($\text{weight (kg)/height (m}^2\text{)}$). Using BMI is simple, fast, inexpensive, and does not require as much training for research assistants compared to other methods, such as hydrostatic weighing. BMI is now widely recommended for pediatric use (Semiz et al., 2007; Barlow & Dietz, 1998; Prentice, 1998). Based on research by Cole et al. (2000), the BMI cut-offs for overweight among children aged 11-14 years old are 21.5 and 22.0 kg/m^2 for boys and girls, respectively. The cut-offs for obesity are 25.6 and 26.3 kg/m^2 for boys and girls, respectively. Using BMI has its disadvantages. For example, it is not a good estimate of body fatness in children not only because it does not measure composition, but also because it does not consider varying growth rates and maturity levels (Maynard et al., 2001).

Skinfold thickness measurements are another surrogate for OWOB. In this method, a pinch of skin is measured by calipers at many points on the body, such as the triceps area, to determine the subcutaneous fat layer thickness. Equations are then used to convert these measurements into an estimated body fat percentage. The advantages of this method include: inexpensiveness, quickness, and low burden for researchers and participants. However, this method has several disadvantages. Semiz et al. (2007) found that skinfold techniques have low validity in obese children. Other issues include: inability to control inter- and intra-subject variation in the skinfold compressibility, the inability to palpate the fat-muscle interface, and the impossibility of obtaining interpretable measurements on obese participants (Himes et al., 1979; Haymes et al., 1976).

Waist-to-hip girth ratio (WHR) is another proxy measure of OWOB. WHR is the ratio of an individual's waist girth to their hip girth. This method is inexpensive, fast, and simple, but it has several disadvantages. For example, WHR in children and adolescents may not be a good index to show intra-abdominal fat deposition (Semiz et al., 2007). Also, there is no correlation between WHR and visceral fat in children (Goran et al., 1995; Fox et al., 1993).

Waist circumference (WC) is another proxy measure of OWOB. It is the circular distance around one's waist, usually measured in cm or inches. The advantages of using WC include: quickness, simplicity, inexpensiveness, and a strong correlation ($r=0.8$) with visceral adiposity (Brambilla et al., 2006). WC has the same problem as BMI since it cannot directly measure composition (and cannot differentiate between lean and fat mass).

There is a discrepancy in the literature over whether or not WC is superior to BMI in identifying overweight and obesity in youth populations. Neovius et al. (2005) compared the ability of WC and BMI to detect fatness in 474 adolescents using air-displacement plethysmography as the reference test, and found that that WC was better than BMI. However, Reilly et al. (2010) found that using WC over BMI has no advantage in detecting high fat mass in 7722 children aged 9-10 years old using dual energy x-ray absorptiometry (DXA) as the reference test. In this study, specificity and both positive and negative predictive values were higher for BMI. In a study by Lazarus et al. (1996), BMI was used to identify overweight and obese children based on body fat percentage. The researchers found that BMI had high sensitivity (95-100%), but low-moderate specificity (36-66%). DXA, hydrostatic weighing (the gold standard, but not as accurate as DXA), whole-body-air-displacement plethysmography, and other expensive techniques are accurate ways to measure body fat and OWOB. Although these techniques are very accurate, BMI and WC are more feasible proxy measures of OWOB in large epidemiologic studies.

OWOB is a condition in which individuals accumulate an excessive amount of body fat based on several standardized charts. Unfortunately, there is no clear consensus on a BMI or WC cut-off point for OWOB in children and adolescents (Dehgan et al., 2005). However, the use of the 85th and 95th percentile to identify overweight and obesity, respectively, is very common in the literature and recommended by several researchers (Barlow & Dietz, 1998; Cole et al., 2000; Flodmark, 2004).

BMI and WC are the appropriate proxy measures of OWOB in large field studies. They have more merit than skinfold measurements and WHR in the literature. Although

they do not measure composition or are not as objective as better methods such as hydrostatic weighing, they are more feasible and realistic for large field studies.

2.1.3 Energy Intake

Energy intake is the consumption of calories (energy) from sources of food and beverages, and it is essential for survival. Based on Dietary Reference Intakes (DRI) from Health Canada, boys and girls aged 9-13 years old should be consuming approximately 1800 and 1600 kcal/day, respectively, with 45-65% from carbohydrates, 10-30% from protein, and 25-35% from fats. These energy intake numbers were calculated in girls 9-13 years old using the median height of 1.44 m and weight of 37 kg. In boys, the median height and weight were 1.44 m and 36 kg, respectively. Sedentary physical activity level was also assumed in these calculations for both genders. During puberty and maturation, children and adolescents increase their energy intake as they require more energy for their bodies to develop and mature (Shomaker et al., 2010; Story, 1992; Bitar et al., 2000; Sun, Gower et al., 2001).

When it comes to energy intake measurement, food frequency questionnaires (FFQ) are very common proxy measures in the literature. A FFQ is a large, self-administered dietary survey which asks the respondent to report the frequency of long-term food and beverage consumption. Examples of common FFQ include: the Block Questionnaire and the Harvard FFQ. They have moderate correlation coefficients against other measures of energy intake, such as diet records and 24 hour recalls, which will be discussed below (Thompson & Byers, 1994), ranging from 0.4 to 0.7. The Harvard FFQ, developed by Walter Willett, is a 147-question semi-quantitative survey commonly used

in large epidemiologic studies. This questionnaire has been validated (Willett, 2001; Willett et al., 1985). The advantages of this method include: simplicity, inexpensiveness, low burden for the participant, easy data entry and analysis, and quickness. The limitations of FFQ include: recall bias, social desirability bias, subjectivity in estimating portion sizes, self-administration, and a moderate degree of literacy and numeracy skills are needed (Hill & Davies, 2001; Gazzangia & Burns, 1993).

Another way to collect energy intake information is by using intake records (Trumble-Waddell et al., 1998). Intake records are a list of all foods and beverages consumed over usually three to seven days. A big advantage of this method is that it is more representative of the diets of individuals compared to other methods, such as FFQ, since the record is over a longer period of time and includes both week days and weekends. The disadvantages include: burden for the participant, decreased motivation for participant to diligently record over time, recall bias, expensiveness, and coding and data entry errors.

A 24-hour recall is another method to assess energy intake. In this method trained nutritional professionals interview participants and record everything they consume in the past 24 hours. The advantages of this method include: low burden for the participant, quickness, and minimal participant literacy requirements. The disadvantages of 24-hour recalls include: it is not representative of habitual intake, recall bias, and expensiveness due to high interviewer burden.

Another common measurement of energy intake is a diet history. This method is similar to a 24-hour recall in that a trained nutritional professional interviews the participant. A key advantage of this method is collecting information regarding allergies,

supplement use, and daily and seasonal eating patterns. Other advantages include: minimal participant literacy skills, details of individual food items are obtained, and reasonably high accuracy. The disadvantages of diet history include: expensiveness, burden for researchers, the resulting data depends heavily on the interviewer's skills, and burden of the for the participant as the sessions are very long (over one hour).

The FFQ is the most appropriate method for energy intake data collection in large field studies (Keshteli et al., 2014). 24-hour recalls and diet history are better methods due to lower recall bias and under-reporting, however, they are not feasible for these types of studies. The Harvard FFQ, for example, has been validated, and its simplicity, quickness, and inexpensiveness make it optimal for large field studies (Keshteli et al., 2014).

The relationship between energy intake and OWOB is important. Excessive energy intake can lead to OWOB if energy expenditure is low (Bowman & Vinyard, 2004; McCorry et al., 2002). Hence, energy intake is positively associated with body weight (or OWOB). However, many researchers have found negative associations between energy intake and OWOB or body mass in children aged 10-14 years old (Skinner et al., 2012; Rocandio et al., 2001; Bandini et al., 1999; Llunch et al., 2000; Tucker et al., 1997; Stewart et al., 1999; Garaulet et al., 2000; Ritchie, 2012; Fabry et al., 1966). The summary of these studies is found in Appendix D. These authors found that the higher the energy consumption, the lower the body mass or OWOB. If all factors are held constant, such as energy expenditure, it is biologically implausible that a higher energy intake leads to a lower body mass or OWOB. Therefore, in these studies, either energy expenditure was not sufficiently measured or energy intake was not accurately

measured. Most notably in these studies was that physical inactivity and resting metabolic rate was not considered. A common dietary methodology limitation in large field studies is under-reporting, especially in overweight and obese children (Gazzangia & Burns, 1993; Johnson-Down et al., 1997). Another potential reason for finding negative associations in cross-sectional studies is the timing of obesity onset (Skinner et al., 2012). In this scenario, some children are OWOB during the time of the study, but they have decided to lower their energy intake prior to the study in attempt to lose weight. This means that although they are currently OWOB, they are truthfully (and unexpectedly) eating less. This issue can be resolved by longitudinal studies since they are able to track energy intake and OWOB patterns over time.

2.1.4 Physical Inactivity as a Proxy of Energy Expenditure

Energy expenditure is the sum of internal heat produced and external work. Due to a higher amount of muscle content, energy expenditure is higher for OWOB children compared to normal weight children (Maffeis et al., 1994; Maffeis et al., 1996; Yu et al., 2002) and boys compared to girls (Bitar et al., 2000; Hoffman et al., 2000). Physical activity accounts for 15-30% of expenditure, approximately 70% comes from resting metabolic rate (RMR), and 10% from the thermic effect of food (van Baak, 1999). Research has shown that OWOB children have a higher RMR than normal weight children in both boys and girls due to higher amounts of muscle mass (Epstein et al., 1989; Yu et al., 2002). However, there were no RMR differences between boys and girls, regardless of weight category (Epstein et al., 1989; Yu et al., 2002; Haffman et al., 2000). Boys have higher energy expenditures than girls since they have higher levels of physical

activity (Melby et al., 1993). Researchers have hypothesized that since physical activity increases muscle mass, it may increase RMR (Goran et al., 1999; Poehlman, 1993; Speakman & Selman, 2003). However, the entire picture of the energy balance must be reviewed, especially the possibility that a change in one component of energy expenditure can result in a compensatory change in other components and changes in energy intake (Goran et al., 1999). Also, the hypothesized increase in RMR depends on several other factors, such as genetics and the activity duration, intensity, type, and frequency (Speakman & Selman, 2003; Poehlman, 1989).

Physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure (WHO, 2010). It is very important since it has many health benefits including: strengthening muscles, boosting the immune system, and helping prevent obesity and cardiovascular disease (Stampfer et al., 2000; Hu et al., 2001). Physical inactivity, an important determinant of obesity (WHO, 1998; Jolliffe, 2004; Tremblay & Willms, 2000), is insufficient physical activity. Canadian children who do not meet the physical activity guideline of at least 60 minutes of moderate to vigorous physical activity per day are physically inactive (Colley et al., 2011). Physical inactivity is more important to consider than physical activity since it is more correlated to health problems, such as OWOB (Pietiläinen et al., 2008). This is also why most researchers use physical inactivity opposed to physical activity in the literature. Physical activity and inactivity cannot determine how much energy is expended, but they are proxy measures of energy expenditure. Physical activity questionnaires have been validated as proxies for energy expenditure against doubly labeled water (Starling et al., 1999; Staten et al., 2001).

Physical inactivity is the fourth leading risk factor for global mortality, causing approximately 3.2 million deaths (WHO, 2010). The vast majority of children are inactive. Less than 10% of Canadian children and youth meet the current guideline listed above (Colley et al., 2011). Physical inactivity is positively associated with OWOB due to an imbalance between energy intake and energy expenditure (Daniels et al., 2005). Those who are physically inactive in childhood tend to remain inactive throughout adulthood (Biddle, Gorely, & Stensel, 2004). Hence, it is important to find ways to reduce physical inactivity early in childhood.

Physical inactivity is difficult to measure because some common methods struggle with accuracy and reliability. Often times, questionnaire are used instead of accelerometers or pedometer. Unfortunately, accelerometers and pedometers only measure physical activity when they are worn and worn properly. Children engage in physical activity even when they remove these devices, such as playing contact sports or even showering. Some children do not properly wear the devices. Hence, activity may be under-estimated. Also, pedometers only measure steps taken during some activities, such as running or walking. They do not work for other activities, such as bicycling.

Questionnaires are common methods of physical inactivity measurement. These tools used to collect information, such as the time spent watching television or playing video games. The advantages of these tools include: low participant burden, simple data collection and analysis, inexpensive, and fast. The disadvantages of questionnaires include: recall bias, social desirability bias, unable to estimate energy expenditure, and subjectivity. A comprehensive tool used in the literature is the Participation Questionnaire (PQ), which is a 61-item questionnaire that asks children to report their

participation levels regarding seasonal recreational pursuits, free-time play, and various sporting activities. This questionnaire has strong construct validity and good test-retest reliability (Hay, 1992; Hay, 1999). Another common measurement tool used in field studies is the Godin Leisure-Time Exercise Questionnaire (Godin & Shephard, 1985), which was previously validated (Sallis et al., 1993). In this questionnaire, children record the amount of time spent on three different levels of physical activities during the past seven days. The Australian Physical Activity Recall Questionnaire, which assesses the type of activity, frequency, and duration of physical activity, is another questionnaire that has previously been validated by Booth et al. (2002).

Questionnaires are appropriate methods for physical inactivity measurement in large field studies. Although accelerometers are more objective tools, they are not feasible for these studies. Therefore, questionnaires, such as the PQ, are reasonable tools to measure physical inactivity in large epidemiologic studies.

The positive association between physical inactivity and OWOB has been established in the literature. Sedentary behaviour (primarily television viewing) has been positively associated with adiposity and excessive weight gain in youth (Danner, 2008; Rey-Lopez et al., 2008; Must & Tybor, 2005). Fulton et al. (2009) sampled children aged 10-18 years old and used a questionnaire to measure the time spent on moderate-to-vigorous physical activity (MVPA). The researchers found that the lower the MVPA, the higher the BMI. Further, it is important to consider physical inactivity when studying OWOB.

2.1.5 Maturity

During pubertal development there are many changes and processes occurring. For example, there are increases in growth hormone, insulin-like growth factor I, gonadotropin, and sex steroid hormone secretion (Smith et al., 1989; Albertsson-Wikland, 1997). During this time, children tend to increase their energy intakes since their bodies demand more energy for development and maturation (Shomaker et al., 2010). Also, their energy expenditure increases result of the bodily changes occurring (Bitar et al., 2000). Puberty is characterized by fast physical changes in body size, shape, and composition in both boys and girls (Siervogel et al., 2003). During puberty, changes in body composition occur, such as increases in fat-free mass (FFM) and decreases in body fat content, mainly in boys, and increases in fat content in the hips and breasts of girls (Smith et al., 1989; Malina & Bouchart, 1991; Roemmich et al., 1998). These changes are seen in changes in BMI, but there are gender differences (Kaplowitz et al., 2001, Wang et al., 2002; Vizmanos & Marti-Henneberg, 2000). Girls who enter puberty early tend to have a higher BMI (Kaplowitz et al., 2001; Wang et al., 2001) whereas boys who enter puberty early tend to have a lower BMI (Wang et al., 2002; (Wang, 2002; Vizmanos & Marti-Henneberg, 2000). Therefore, when studying OWOB, it is important to consider maturity differences.

During puberty there is marked sexual dimorphism in the relationships between age, growth, and sexual maturation (Shomaker et al., 2010). Girls usually start rapid linear growth at the same time as their first appearance of breast development (Tanner breast stage 2). They usually complete most of their linear growth by 13 years of age before completing breast development (Tanner breast stage 5). Males typically achieve peak linear growth velocity later in pubertal development than girls.

Peak height velocity (PHV) is a proxy measure for maturity. It reflects the maximum velocity in stature growth during adolescence, and has found to be highest in early-maturing children (Tanner & Davies, 1985). Age-to-peak height velocity (APHV) is used to predict how far an individual is from peak height velocity. Gender, age, height, sitting height, leg length, and weight are needed to calculate APHV. There is measurement bias in the way leg length is calculated which will be discussed later. APHV does not measure sexual development like Tanner stages, however, it is related to puberty since it is an indicator for maturity among adolescents. APHV is correlated to the age at Tanner testis stage 2 or breast stage 2 (Val Abbassi, 1998; Tanner & Whitehouse, 1976).

2.1.6 Residence and Gender

One environmental factor for OWOB which can influence energy expenditure is geographical location (either urban or rural environment). The literature is ambivalent in terms of whether or not there is a difference in OWOB between urban and rural children. Some studies have found that rural children are more OWOB than their urban peers (Liu et al., 2008; Belfort et al., 2012) partly due to higher physical inactivity since these children are more likely to receive transportation to school (Plotnikoff et al., 2004). Other studies have either found the opposite or no differences (Hodgkin et al., 2010; Booth et al., 2002; Bruner et al., 2008). Whether or not there is a difference between rural and urban children, geographical location is important to consider when studying OWOB.

Gender is important to consider when studying obesity. There is a gender difference in the prevalence of OWOB as described in the background section in 2.1.1. Across all ages among children and adolescents, girls tend to have a higher BMI than boys, but after gender-adjustment, boys tend to be more overweight or obese (Cole et al., 2000). Using BMI, Garaulet et al. (2000) found that among 331 adolescents aged 14-19 years old, the prevalence of overweight or obesity status in boys was 48% compared to only 31% in girls. Using BMI cut-offs from Cole et al. (2000), Lobstein & Jackson-Leach (2007) conducted a similar analysis among children aged 12-17 years old. The authors found a slightly higher prevalence of OWOB in boys compared to girls. The prevalences of overweight and obesity were 23% and 15% in boys, respectively, compared to 21% and 13% in girls.

2.2 Probable Developmental Coordination Disorder

2.2.1 Developmental Coordination Disorder Background

Developmental coordination disorder (DCD) is neuro-developmental disorder characterized by significant impairment of motor skills (American Psychiatric Association, 1994; Kirby et al., 2008) that interfere with everyday activities (Gibbs et al., 2007; Kadesjo & Gillberg, 1999). Awareness of motor deficiency was documented as early as 1925 by Dupre who referred to *debilite motrice* (motorically deficient) when describing the condition (Dupré, 1925). Children with DCD have been pejoratively labeled as clumsy and awkward (Orton, 1937). Further, the condition was referred to as *congenital clumsiness* by Collier (Ford, 1966; Vaivre-Douret, 2007). Congenital motor impairments are usually termed dyspraxia, a constitutional developmental disorder

involving impairment in learning or in performing non-habitual motor tasks (Vaivre-Douret et al., 2011). This term is frequently used interchangeably with DCD and often regarded as synonymous by neuropsychologists, neurologists, and physicians.

There has been confusion and inconsistency in the literature due to unclear terminology for DCD. The disorder appears to be a collection of conditions lacking clearly defined clinical signs and symptoms or any specific disorder within the definitions of other developmental disorders, such as Autism or attention deficit disorder (Vaivre-Douret et al., 2011). After a consensus meeting in 1994, the term DCD was selected to describe individuals with significant impairment of fine and gross motor skills (American Psychiatric Association, 1994; Gueze, 2007). This term is in both the Diagnostic and Statistical Manual for Mental Disorders (American Psychiatric Association, 2000) and the International Classification of Diseases and Related Health Problems (World Health Organization, 1992). DCD is the most recent, formal, and widely used term to describe individuals with this condition (Kirby et al., 2008; Polatajko & Cantin, 2005). The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM5) defines DCD as a motor disorder in the neuro-developmental disorder category (American Psychiatric Association, 2013).

DCD is a disorder of motor skills which impairs the development of motor coordination (American Psychiatric Association, 1994). The motor abilities of children with DCD are much lower compared to their peers (American Psychiatric Association, 2000) in the absence of co-morbidities, such as cerebral palsy, intellectual disabilities, toxic and teratogenic disorders, malignancies, and inflammatory brain disorders (Blank et

al., 2012). There are four DSM5 criteria involved in the diagnosis of DCD which include:

- A) Acquisition and execution of coordinated motor skills are below what would be expected at a given chronologic age and opportunity for skill learning and use; difficulties are manifested as clumsiness and as slowness and inaccuracy of performance of motor skills.
- B) The motor skills deficit significantly or persistently interferes with activities of daily living appropriate to the chronologic age and impacts academic/school productivity, prevocational and vocational activities, leisure, and play.
- C) The onset of symptoms is in the early developmental period.
- D) The motor skills deficits cannot be better explained by intellectual disability or visual impairment and are not attributable to a neurologic condition affecting movement. (American Psychiatric Association, 2013).

Children with DCD lack the basic motor skills to perform simple activities, such as playing games, dressing, grooming, handwriting, and eating (Missiuna et al., 2011; Gueze, 2007; Wang et al., 2009). Due to motor difficulties, these children tend to avoid participation in free and organized play (Cairney et al., 2005b; Cairney et al., 2007; Silman et al., 2011). In a review of activity patterns among children with DCD, Magalhaes et al. (2011) found that these children experienced difficulties in play-related activities (riding a bicycle, jump rope, using playground equipment, running, and jumping), classroom tasks (handwriting), language and speech, self-care tasks (dressing and using cutlery), and socializing. These findings support the claim that children with

poor motor skills experience great obstacles in performing everyday activities, and more attention should be geared toward helping them.

2.2.2 Diagnosis

The Bruininks-Oseretsky Test of Motor Proficiency Short Form (BOTMP-SF) is the often used in large field studies to classify p-DCD, when the long form of this test is too time-consuming and costly. This test is reliable and has been validated. Children's motor difficulties are often evaluated by themselves or their parents prior to any diagnosis (Cairney et al., 2008; Green & Wilson, 2008; Cairney et al., 2007; Dunford et al., 2005). The BOTMP-LF is a common diagnostic test for DCD, and it is administered by professionals, such as trained psychologists or occupational therapists (Miller et al., 2001). This test was previously used as the reference standard in DCD diagnosis (Gwynne & Blick, 2004), however, there is currently no universally accepted gold standard (Missuina et al., 2006). The Motor Performance Checklist (MPC) test was compared to the BOTMP-LF in a study involving 141 5-year-olds by Gwynne & Blick (2004). Correlations of 0.72 and 0.85 were found between the tests, and the positive predictive validity and negative predictive validity were 72% and 99%, respectively. The most widely used diagnostic test in the United Kingdom is the Movement Assessment Battery for Children 2 (M-ABC2), which was designed to diagnose DCD in children between 4 and 12 years (Henderson & Sugden, 1992; Henderson & Sugden, 2007). This is a revision of the M-ABC test, and it requires clinical judgment by research technicians (Cairney et al., 2009a).

When the M-ABC2 is not feasible in large field studies the short form of the BOTMP (BOTMP-SF) is used instead. This test examines motor proficiency (static and dynamic balance, reaction time, bilateral coordination, and more) using items from the long form. This short form test only takes 30 minutes to complete compared to 2 hours for the long form. The short form has been validated against the long form with intercorrelations between 0.90 and 0.91 for children between 8-14 years of age (Bruininks, 1978). The greatest limitation of this test is that it only measures the ability of the participant to perform an activity, not the quality of movement (Missiuna et al., 2006; Larkin et al., 2005; Cairney et al., 2009a; Spironello et al., 2009). Also, while the BOTMP is objective, it does not require clinical judgment, which is both a strength and weakness.

In a diagnostic trial by Spironello et al. (2009), the agreement between the BOTMP-SF and the M-ABC in detecting the disorder was poor. Other authors have questioned the validity of the BOTMP-SF for DCD diagnosis (Missiuna et al., 2006; Dewey & Wilson, 2001). Cariney et al. (2009a), however, they concluded that the BOTMP-SF is a reasonable alternative for DCD diagnosis when the M-ABC is not feasible. The authors reported a positive predictive value of 88% and 63% for the BOTMP-SF using the M-ABC cut-point of the <15th percentile and <6th percentile, respectively.

The BOTMP-SF is an appropriate tool to use for p-DCD classification in large epidemiologic studies. Other methods, such as the long form version of this test, are better tools, but may not be feasible in such large studies. Therefore, the BOTMP-SF is an appropriate method for classifying p-DCD in these types of studies.

2.2.3 Prevalence

The prevalence of DCD in Canadian school-aged children is between 5% and 6% (Gibbs, Appleton, & Appleton, 2007) making DCD the most prevalent childhood disorder (Cairney et al., 2007). Depending on the application of diagnostic criteria, the prevalence of DCD has been reported in the range of 1.8% to 9% in children aged 9 to 11 years old (Lingam et al., 2009; American Psychiatric Association, 1994; Kadesjo & Gillberg, 1999; Cermak & Larkin, 2002; Gaines et al., 2008). The most definitive study was by Lingam et al. (2009) who reported a prevalence of 3%.

The condition is more common in males than females. Some studies suggested males are two times more likely to have DCD than females (Lingam et al., 2009; American Psychiatric Association, 2000). Other studies have reported the prevalence of DCD to be between three (Miller et al., 2001) and seven (Kadesjo & Gillberg, 1999) times higher in males than females. The different numbers in males and females could be related to a gender bias in the assessment tools used in DCD diagnosis (Lefebvre & Reid, 1998). Stereotypes of boys being more physically active in the schoolyard may identify boys with motor impairments easier than girls (Rivard, Missuina, Hanna, & Wishart, 2007). Also, referral bias may have a role since girls have a lower social expectation for involvement and competence in sports and physical activity (Hay & Donnelly, 1996). Therefore, girls are less likely to be referred for assessment or help compared to boys.

2.2.4 Potential Causes

The cause of DCD is unknown, but recent research has suggested that it has a genetic component (Lichtenstein et al., 2010) and is associated with perinatal oxygen

perfusion problems (Pearsall-Jones et al., 2009). Research has also suggested that premature births and central nervous system pathologies, such as inter- or intra-hemispheric connection disorders (Geschwind, 1975) and basal ganglia dysfunction (Lundy-Ekman et al., 1991), are potential causes (Vaivre-Douret et al., 2011; Zwicker et al., 2009; Zwicker et al., 2012). Using magnetic resonance imaging (MRI) on participants with DCD, Querne et al. (2008) found increased brain activity in the middle frontal cortex and anterior cingulate cortex in the left hemisphere and decreased activity between the striatum and parietal cortex in the right hemisphere. The authors concluded that DCD could be characterized by abnormal brain hemispheric specialization during early development. Children with DCD had lower axial diffusivity in motor and sensory tracts in a study by Zwicker et al. (2012). The cause of DCD is unknown, however, the disorder is likely caused by a neuropathology in-utero.

2.2.5 Physical Inactivity and Developmental Coordination Disorder

Children with p-DCD are more physically inactive than their non-DCD counterparts (Cantell et al., 1994; Cairney et al., 2007; Cairney et al., 2005b; Wrotniak et al., 2006). Children with p-DCD have a physical activity deficit even when compared to the increasingly inactive population of children without p-DCD. In a review by Rivilis et al. (2011), the authors found that poor motor proficiency was associated with lower levels of physical activity and participation in free and organized play in 20 of 21 studies. Children with poor adequacy and predilection for physical activity had lower motor competence, and were less physically active in organized and free play (Hay & Missiuna, 1998). The authors found a positive correlation between BOTMP score and physical

activity ($r = 0.57$), and this grew stronger with age. Among children aged 8-9 years old, those with low compared to high motor competence had lower scores on the Leisure Score Index (Cantell et al., 2008). In comparison to children without p-DCD, children with p-DCD chose activities that were quieter and more socially isolated (Jarus et al., 2011). Children with motor difficulties spent an average of 5.7% less time than their matched classmates in adoptive behaviors during physical education classes (Causgrove et al., 2006). Smyth & Anderson (2000) found that children without p-DCD participated in significantly more formal and informal team games and spent less time alone in the playground than children with the disorder. Therefore, based on the above literature, children with DCD are more inactive than their peers.

In another study, Poulsen et al. (2008) found that boys with p-DCD aged 10-13 years old had lower scores of energy expenditure (estimated using metabolic equivalent of task scores) than controls. They also found that the peer relations self-concept (an indicator of one's perceptions of relationships with others) was a significant mechanism mediating the relationship between motor proficiency and low energy expenditure. In addition to peer relationships, it has been shown that lower physical self-efficacy in children with p-DCD partly explains why they are less physically active than their developing peers (Cairney et al., 2005a; Cairney et al., 2005b). Cairney et al. (2005b) found that girls compared to boys with p-DCD reported the lowest levels of generalized self-efficacy and participation in organized activities and free play. The gender difference in physical activity participation can be partly explained by the lower enjoyment in girls than boys (Klentrout et al., 2003).

Similar results were found in other studies using more objective measures of physical activity, such as pedometers. Castelli & Valley (2007) found a significant, positive correlation between the total motor competency score and the number of steps taken during formal activity programs measured by a pedometer ($r=0.54$). Wrotniak et al. (2006) found that children in the highest quartile of motor proficiency (based on BOTMP scores) were more active and spent more time doing moderate-vigorous physical activity (measured by accelerometers) compared to the lower quartiles. Similar results were found in previous studies (Okely et al., 2001; Williams et al., 2008; Fisher et al., 2005). Furthermore, Wrotniak et al. (2006) found that motor proficiency explained 8.7% of the variance in physical activity after controlling for gender, socioeconomic status, children's BMI, and others.

The relationship between motor proficiency and physical activity has also been examined longitudinally. In a study by Cairney et al. (2009b), children with compared to without p-DCD continued to have lower levels of participation in physical activity after three years. In a six-year longitudinal study, Barnett et al. (2009) found that being able to competently perform object control skills in childhood may be a significant predictor of physical activity engagement during adolescence. Children with good compared to poor object control skills had a 20% greater chance of participating in some vigorous activity during adolescence (six years later). Other studies have found that although children with compared to without p-DCD continued to have lower levels of participation in physical activity, the gap did not widen over time (Rivilis et al., 2011).

2.2.6 Overweight or Obesity Status and Developmental Coordination Disorder

Children with compared to without DCD have a higher BMI and more likely to be OWOB (Cairney et al., 2011; Cairney et al., 2010; Hands & Larkin, 2006; Cantell et al., 2008; Schott et al., 2007). Children with DCD are more inactive than their peers in organized and recreational activities (Hay & Donnelly, 1996; Hay et al., 2004). It is known that physical activity is an important determinant of obesity (WHO, 1998; Jolliffe, 2004; Tremblay & Willms, 2000). Therefore, these children are placed at a higher risk of becoming OWOB (Cairney et al., 2005b). Using bioelectrical impedance analysis and BMI to assess OWOB, Cairney et al., (2005b) found that children aged 9-14 years old with DCD were more overweight or obese than those without DCD, but this result was only seen in boys. The gender difference could be due to either low power (the sample size was small) or a *floor effect* in which girls tend to have lower levels of physical activity compared to boys, and therefore, girls with DCD may not have been at a greater risk for overweight or obesity since their levels of physical activity were not significantly different from their motor-proficient peers. Chirico et al. (2010) found that children with DCD had significantly higher body fat percentages (28.3%) than children without DCD (20.0%) using air-displacement plethysmography. In a two-year longitudinal study, Cairney et al. (2010) found that the greater risk of overweight and obesity among children with compared to without DCD did not diminish over time. Therefore, children with DCD are more OWOB than their peers.

Researchers have not looked at energy intake differences among children with and without p-DCD. This is an important area of research since energy intake is essential to the energy balance equation. Regarding this energy balance, it is important to determine if the energy intake and body mass association in children with p-DCD is

similar to the ones found in the general population of children described in the above literature, after taking into account physical inactivity (as the proxy for energy expenditure).

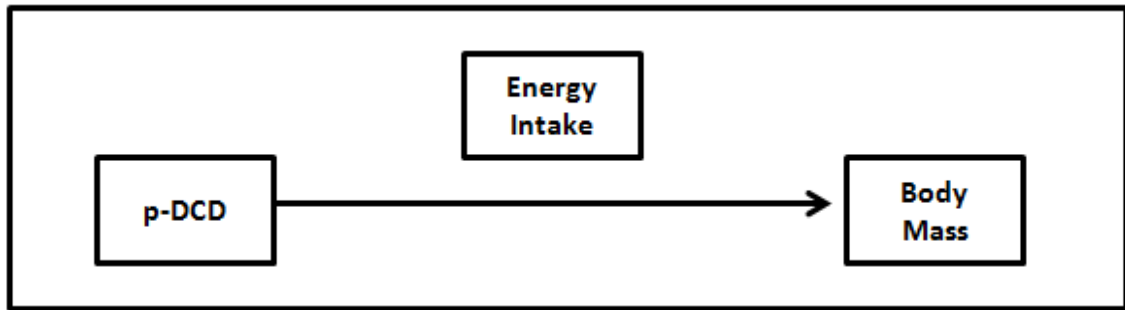
2.3 Summary: Linking p-DCD, Energy Intake, and OWOB

The prolonged energy imbalance leads to OWOB. It has been established that the increased inactivity is positively associated with OWOB among children with p-DCD, however, energy intake has not been considered previously. This study will investigate the influence of energy intake on OWOB in p-DCD children.

2.4 Purpose, Objective, and Hypothesis

It is known that p-DCD children are more inactive and OWOB than their peers. It is also known their physical inactivity is positively associated with their body mass. However, there is an absence of energy intake knowledge in the p-DCD literature. The purpose of this study is to investigate the influence of energy intake in the relationship between p-DCD and OWOB (Figure 2.4). The objective is to examine energy intake (estimated in the FFQ) as it influences OWOB (through the proxy of BMI) in children with p-DCD (classified by the BOTMP-SF) after controlling for energy expenditure (using physical inactivity as a proxy measured in the PQ). Based on the literature (Bowman & Vinyard, 2004; McCorry et al., 2002), it is hypothesized that energy intake will be positively associated with OWOB in p-DCD children after controlling for maturity status, residence, and physical inactivity.

Figure 2.4 Assessing the association between energy intake and body weight in children with p-DCD

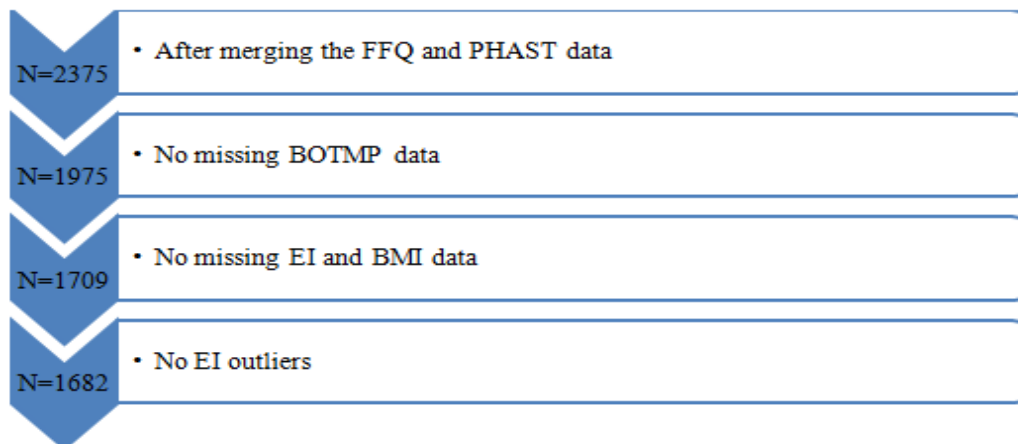


3.1 Study Population

This study involved 1975 participants of the original 2519 at the start of Phase I of the Physical Activity Health Study Team (PHAST). PHAST was funded by the Canadian Institutes of Health Research (CIHR) and followed students for six years from grade 4 (2004) to grade 9 (2010) in the District School Board of Niagara (DSBN). The PHAST study received Research Ethics Board approval from Brock University and the DSBN. All elementary schools in the DSBN were eligible to participate in the study, and of 92 schools, 75 (83%) participated with informed parental consent provided for 2278 (96.8%) of 2395 children.

Data was examined from the winter (January-March) term of grade 7 in 2007. Those with missing EI data included did not differ in terms of gender, age, and BMI compared to those without missing data excluded (see Appendix A). Of the 1975 participants in this study, 1709 (86.5%) had no missing information on p-DCD status, energy intake, and BMI (see Figure 3.1).

Figure 3.1. Cleaning of the data



3.2 Key Study Variables

3.2.1 Probable Developmental Coordination Disorder

The independent variables in this study were p-DCD and energy intake. Children were classified as having p-DCD if they scored at or below the 10th percentile on the BOTMP-SF (Cairney et al., 2007). p-DCD was not measured among all the students at the same time. This is not a problem since the condition is constant, and if a child has p-DCD at one point in time, then that child will still have the condition if measured later in time. The short form test of motor proficiency contains 14 items that examine basic motor skills, such as balance, agility, bilateral coordination, strength, upper-limb dexterity and coordination, and response speed. The short form test has been validated against the long form with correlations between 0.90-0.91 (Bruininks, 1978). The term probable DCD was used here since the identification of cases was through the results of a field test administered by research assistants, instead of a full diagnostic protocol done by a trained physician.

3.2.2 Energy Intake

Information on nutrient intakes and dietary patterns was recorded on the Harvard Medical School (HMS) Eating Survey (C-02-1). The survey has previously been validated against multiple diet records and 24-hour recalls with moderate correlations for EI at $r=0.51$ (Longnecker et al., 1993; Willett et al., 1985; Hernandez-Aliva et al., 1998). This FFQ consisted of 147 questions based on 77 food items, and took about 25 minutes to complete. The responses were ordinal in nature, for example:

4. *How many teaspoons of sugar do you ADD to your beverage or food each day?*

a) *none/less than 1 teaspoon per day*

b) *1-2 teaspoons per day*

c) *2-3 teaspoons per day*

d) *5 or more teaspoons per day*

The students completed the surveys during school hours. The surveys were sent to Harvard Medical School (Boston, MA) where daily nutrient intakes of macronutrients (protein, carbohydrate, total, saturated, trans, monounsaturated, and polyunsaturated fat), minerals (calcium, iron, magnesium, phosphorus, magnesium, iron, potassium), and vitamins (C, A, D, E, and folate) were computed through the *Nutrition Quest Data-On-Demand System* (Berkeley, CA). In this study, energy intake (kcal/day) was estimated using this questionnaire data. Participants whose $EI > 5483.2$ kcal/day were removed since they were extreme outliers equal to or more than three standard deviations above the mean (Ruan et al., 2005). There were no energy intake values greater than three standard deviations below the mean. The lowest energy intake value was 470.4 kcal/day, which was not even two standard deviations below the mean.

3.2.3 Overweight or Obesity Status

OWOB was the dependent variable in this study. This variable was coded as “yes” or “no” being either overweight or obese based on the age and gender adjusted BMI cutoffs of 22.02 kg/m^2 for females and 21.48 kg/m^2 for males using the 85th percentile (Cole et al., 2000). Body mass index (BMI) was calculated using height and weight (kg/m^2), which were measured in a private room with the parent(s) consent.

Standing height (cm) was measured using a standiometer (Stat 7X, Ellard Instrumentation Ltd Monroe, WA, USA) and recorded to the nearest 0.1 cm. Weight (kg) was measured using a digital scale (BWB-BOOS, Tanita Digital Scale, Toykyo, Japan) and recorded to the nearest 0.1 kg. The scale was calibrated using a 10 kg weight and subjects were weighed wearing only tight fitting swimsuits or undergarments.

3.3 Covariates

3.3.1 Physical Inactivity

Physical inactivity is a proxy for energy expenditure. It was measured based on data collected by the PHAST study as part of the *Participation Questionnaire (PQ)*. This questionnaire was a 61-item list consisting of eight sections, in which six of them assessed the amount of time spent in organized activity, free-time activity, and sedentary activity by each participant. The PQ has displayed strong construct validity and test-retest reliability of 0.81 (Hay, 1992). Physical inactivity ranged from 0-13 hours, where 13 hours represents the highest level of physical inactivity. There were several items that explored physical inactivity on the PQ. For example: question 18 asks: *how often do you play video games in your spare time?* The responses include: *everyday, almost every day, hardly ever, and never*. Another example is question 16 which asks: *how many hours per day do you usually watch television?* The responses included: *0-1, 1-2, 2-3, 2-4, 4-5, and 5 or more*.

3.3.2 Demographic Data: Age, Gender, and Residence

Age and gender were indicated by participants on the HMS Eating Survey. Age was measured in years and was based on the individuals' section of one of 11 response options ranging from less than 9 to 18 years or older. Ethnicity was not considered in this analysis since the PHAST study was not permitted to collect data pertaining to ethnicity. The District School Board of Niagara has a distinct homogeneity among their students with the majority being Caucasian. Residence was included in the PHAST survey and was measured in the Parental Questionnaire, in which the parents recorded where they live. PHAST researchers dichotomized the participants' residence into either an urban or rural location.

3.3.3 Maturity Status

Age-to-peak height velocity (APHV) was calculated and used as a proxy measure of maturity. APHV is a biological maturity indicator and reflects the maximum velocity in stature growth during adolescence (Mirwald et al., 2002). It is based on the differential growth and timing of leg length and sitting height. The ideal age of prediction is 9-13 and 12-16 years in females and males, respectively. This variable was calculated specific to gender as per the methods of Mirwald et al. (2002) whereby:

$$aPHV_{females} = -9.376 + 0.0001882 * (leg\ length(cm) * sitting\ height(cm)) + 0.0022 * (age\ (yrs) * leg\ length\ (cm)) + 0.005841 * (age(yrs) * sitting\ height\ (cm)) - 0.002658 * (age\ (yrs) * weight\ (kg)) + 0.07693 * (weight\ (kg) / standing\ height\ (cm))$$

$$aPHV_{males} = -9.236 + 0.0002708 * (leg\ length(cm) * sitting\ height(cm)) - 0.001663 * (age\ (yrs) * leg\ length\ (cm)) + 0.007216 * (age(yrs) * sitting\ height\ (cm)) + 0.02292 * (weight\ (kg) / standing\ height\ (cm)).$$

Leg length (a proxy for APHV) was calculated by subtracting sitting height from standing height. There is measurement bias in the way that leg length is calculated in large field studies. Since gluteal fat and muscle is not removed in the calculation, sitting higher is likely to be artificially taller and leg length is likely to be artificially shorter. This translates into an artificially lower APHV. APHV was dichotomized in maturity status (yes or no) based on the gender-separated median cutoff of -2.10 years for females and -2.50 years for males.

3.4 Statistical Analyses

Analyses were completed using SAS 9.3 (SAS Institute Inc., Cary, NC, USA), and the level of significance was set at the two-tailed test with $p \leq 0.05$. Analyses were comparing p-DCD (BOTMP-SF $\leq 10^{\text{th}}$ percentile) to non-DCD (BOTMP-SF $> 10^{\text{th}}$ percentile). Descriptive statistics were used to determine proportions or means and standard deviations for a summary table of the data stratified by p-DCD status. Student t-tests were conducted to test mean differences in energy intake between children with and without p-DCD. Logistic regression analyses were used to assess the association

between energy intake and OWOB in children with and without p-DCD. BMI was the primary dependent variable that was used to create body mass groups (normal weight and OWOB). WC, using the 75th percentile cutoff, was a secondary dependent variable used to create body mass groups (see Appendix C).

Odds ratios and 95% confidence intervals (CIs) were obtained as well as Chi-square statistics using the log likelihood method for model evaluation. Four models were implemented in all logistic regression analyses, and included:

Model 1: Body Mass=p-DCD + Gender + Residence

Model 2: Body Mass=p-DCD + Gender + Residence + PiA

Model 3: Body Mass=p-DCD + Gender + Residence + PiA + energy intake

Model 4: Body Mass=p-DCD + Gender + Residence + PiA + energy intake + Maturity Status

Potential interactions between DCD, gender, and maturity status were also examined. Normal distribution was checked for continuous variables using the Anderson-Darling p-value. Multicollinearity among continuous predictor variables were assessed using the Pearson correlation test and the variance inflation factor.

4.1 Sample Characteristics: Girls and Boys Separately

Overall, the mean age was 12 years for the 1975 participants. Of the 1975 participants, 1709 (86.5%) had no missing information on p-DCD status, energy intake, and BMI. The majority of the missing data was from energy intake. 875 participants (51.5%) were male and 824 (48.5%) were female. The mean age and standard deviation among those without missing data was 12.4 years [0.3 years].

The overall prevalence of p-DCD was 6.0% (4.8% in males and 9.3% in females). Compared to non-DCD children, children with p-DCD had a significantly higher BMI, higher levels of physical inactivity, and lower energy intake and APHV.

p-DCD girls had a significantly lower APHV compared to non-DCD girls, which was not different in boys. There were no energy intake differences between p-DCD and non-DCD boys (2265 vs. 2271 kcal/day, $p=0.972$). However, girls with p-DCD consumed approximately 336 kcal/day less than girls without the disorder (1731 vs. 2067 kcal/day, $p=0.003$).

Table 4.1.1 Characteristics of girls aged 11-13 years old in the PHAST Study (2007) by p-DCD status (N=964)

	p-DCD	Non-DCD	p-value
N	77	887	
Age (yrs, mean [SD])	12.4 [0.3]	12.4 [0.4]	0.348
Rural housing (%)^	23.3	37.5	0.013
BMI (BMI, mean [SD])^	24.1 [5.1]	19.8 [3.8]	0.0002
PiA (score, mean [SD])^	7.9 [1.8]	7.3 [1.8]	0.016
APHV (yrs, mean [SD])^	-2.44 [0.46]	-2.06 [0.42]	<0.0001
EI (g/day, mean [SD])^	1731 [733]	2067 [888]	0.003
EI (g/day, median [Q1-Q3])^	1629 [1117-2100]	1857 [1472-2482]	0.033

PiA physical inactivity; EI energy intake; BMI body mass index; APHV age-to-peak height velocity. ^Indicates sample size change.

Table 4.1.2. Characteristics of boys aged 11-13 years old in the PHAST Study (2007) by p-DCD status (N=1011)

	p-DCD	Non-DCD	p-value
N	42	969	
Age (yrs, mean [SD])	12.5 [0.4]	12.4 [0.3]	0.141
Rural housing (%)^	38.1	35.3	0.711
BMI (BMI, mean [SD])^	23.0 [4.9]	19.7 [3.6]	0.0002
PiA (score, mean [SD])^	9.0 [1.8]	7.5 [2.0]	<0.0001
APHV (yrs, mean [SD])^	-2.37 [0.53]	-2.50 [0.51]	0.111
EI (g/day, mean [SD])^	2265 [1089]	2271 [1025]	0.972
EI (g/day, median [Q1-Q3])^	2026 [1317-2653]	2020 [1540-2764]	0.914

PiA physical inactivity; EI energy intake; BMI body mass index; APHV age-to-peak height velocity. ^Indicates sample size change.

4.2 Correlation Results

Correlation results between key variables, such as motor proficiency, energy intake, and others, are shown below in Tables 4.2.1 and 4.2.2. The correlation between energy intake and BMI was negative in both genders after adjusting for physical inactivity, residence, and maturity ($r=-0.183$, $p<0.0001$ in girls and $r=-0.082$, $p=0.018$). This correlation was approximately twice as strong in girls. The correlation between physical inactivity and BMI was positive in both genders, but only significant among

boys ($r=0.111$, $p=0.001$ in boys and $r=0.064$, $p=0.051$ in girls). The correlation between APHV and BMI was moderate and significant in both genders, but the directions were opposite ($r=-0.440$ in girls vs. $r=0.390$ in boys). These results show that there are gender differences in this study.

Table 4.2.1 Pearson correlation matrix of motor proficiency, body mass index, waist circumference, physical inactivity, energy intake, and age-to-peak height velocity in girls

	MP	BMI	WC	PiA	EI	APHV
MP		-0.348 <0.0001 946	-0.357 <0.0001 946	-0.028 0.392 940	0.090 0.010 828	0.267 <0.0001 930
BMI			0.900 <0.0001 945	0.064 0.051 937	*-0.183 <0.0001 812	-0.440 <0.0001 930
WC				0.073 0.026 937	-0.149 <0.0001 824	-0.314 <0.0001 929
PiA					0.125 0.0004 819	0.009 0.777 921
EI						0.022 0.526 822

*Note: numbers are arranged as such: r-value, p-value, sample size. MP motor proficiency; BMI body mass index; WC waist circumference, PiA physical inactivity, EI energy intake; APHV age-to-peak height velocity. *The correlation between EI and BMI was controlled for physical inactivity, residence, and APHV.*

Table 4.2.2 Pearson correlation matrix of motor proficiency, body mass index, waist circumference, physical inactivity, energy intake, and age-to-peak height velocity in boys

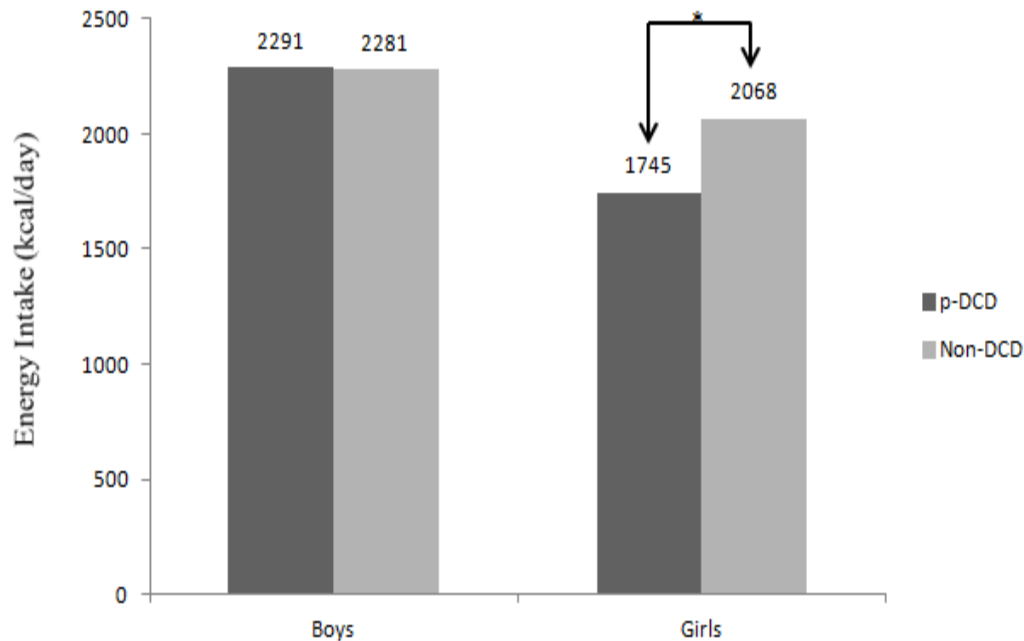
	MP	BMI	WC	PiA	EI	APHV
MP		-0.297 <0.0001 970	-0.319 <0.0001 973	-0.140 <0.0001 978	0.042 0.220 867	-0.043 0.188 950
BMI			0.914 <0.0001 970	0.111 0.001 968	*-0.082 0.018 842	0.390 <0.0001 950
WC				0.130 <0.0001 970	-0.062 0.070 860	0.432 <0.0001 950
PiA					-0.005 0.895 864	0.009 0.797 948
EI						0.0002 0.996 850

*Note: numbers are arranged as such: r-value, p-value, sample size. MP motor proficiency; BMI body mass index; WC waist circumference, PiA physical inactivity, EI energy intake; APHV age-to-peak height velocity. *The correlation between EI and BMI was controlled for physical inactivity, residence, and APHV.*

4.3 Energy Intake in Children with and without p-DCD

Figure 4.3.1 shows energy intake in children with and without p-DCD by gender after controlling for physical inactivity, maturity status, and body mass. The mean level of energy consumed by boys with p-DCD was very similar to boys without p-DCD (2291 vs. 2281 kcal/day, $p=0.917$). However, girls with p-DCD were consuming approximately 323 kcal/day less, on average, than non-DCD girls ($p=0.007$). This result was similar when looking at the median difference (see Figure B2).

Figure 4.3.1 Mean energy intake (kcal/day) in children with and without p-DCD after adjusting for physical inactivity, maturity status, and body mass (N=1683)



Note: Significant difference among girls ($p=0.007$), not boys ($p=0.917$)

4. 4 Logistic Regression Results

The results from the logistic regression are shown in Table 4.4.1 with males and females analyzed separately due gender differences and a significant gender and maturity status interaction ($p<0.0001$) on the odds of OWOB. Maturity status was negatively associated with OWOB in girls. However, the association was positive among boys. Furthermore, the odds of OWOB for children with compared to without p-DCD were over three times greater and statistically significant after controlling for physical inactivity, energy intake, and other covariates in both genders.

There was no interaction between energy intake and p-DCD on the odds of OWOB in both genders ($p=0.342$ in girls and $p=0.079$ in boys). Energy intake was negatively associated with OWOB in girls in Model 3 (0.84 [0.71, 0.99]). Energy intake was not associated with OWOB in Model 3 in boys (0.90 [0.77, 1.05]). The addition of

energy intake increased the OR of p-DCD quite drastically in girls only and added 9.6 new Chi-square units (a 28% increase in the likelihood ratio for the model). The addition of energy intake did not improve the model in boys; in fact it reduced the likelihood ratio for the model.

By Model 4, the association of energy intake with OWOB remained significant in girls, after controlling for physical inactivity, maturity status, and others. The addition of maturity status increased the OR of p-DCD in boys and added 61.8 new Chi-square units (77.8 – 16.0) to the model after controlling for residence, energy intake, and other covariates. A similar trend was seen in girls since the addition of maturity status added 57.9 new Chi-square units (103.1 - 45.2) to the model and largely decreased the OR of p-DCD.

The regression results for physical inactivity in the models are shown in Table C3 (Appendix C). Physical inactivity was positively associated with OWOB in Model 2, but only significantly in boys. By Model 4, after controlling for energy intake, maturity status, and others, the positive association remained significant in boys. The addition of physical inactivity to Model 2 in girls changed the OR of p-DCD very slightly and only added 1.4 Chi-square units to the model (a 4.1% increase). In boys, however, physical inactivity changed the OR of p-DCD largely and added 11.3 Chi-square units to the model (a 58.3% increase).

Also, logistic regression tables were created using high waist circumference as the dependent variable (>75th percentile; >76.0 cm in boys and >76.2 cm in girls) to compare to the results using the BMI cutoffs for OWOB (see Appendix C, Tables C1-2). The results using WC were very similar to the ones above using BMI.

Table 4.4.1 Logistic regression analyses of p-DCD and energy intake on overweight and obesity by gender

	N	p-DCD	Energy intake	χ^2
Boys				
Model 1	991	4.01 (2.13, 7.58)*		19.4
Model 2	858	3.85 (1.88, 7.89)*		16.0
Model 3	858	3.24 (1.56, 6.74)*	0.90 (0.77, 1.05)	16.0
Model 4	858	3.35 (1.57, 7.15)*	0.89 (0.76, 1.05)	77.8
Girls				
Model 1	938	4.17 (2.56, 6.78)*		34.5
Model 2	817	4.89 (2.86, 8.36)*		44.1
Model 3	817	4.74 (2.76, 8.13)*	0.83 (0.70, 0.99)*	45.2
Model 4	817	3.16 (1.78, 5.61)*	0.82 (0.68, 0.98)*	103.1

Overweight and obese ($BMI \geq 21.48 \text{ kg/m}^2$ in boys and $\geq 22.02 \text{ kg/m}^2$ in girls). OR (95% CI); EI transformed to EI/1027.1 for boys and EI/882.9 for girls to make the OR more interpretable. *Indicates statistically significant result ($p < 0.05$). χ^2 indicates likelihood ratio of the model for covariates.

Model 1: included p-DCD and residence.

Model 2: included Model 1 and physical inactivity.

Model 3: included Model 2 and EI.

Model 4: included Model 3 and maturity status.

This is the first study to investigate the influence of energy intake on OWOB in children with p-DCD. In this present study, two new results were found. Firstly, there was a difference in energy intake between children with and without p-DCD in girls only. After controlling for a number of confounding factors, such as physical inactivity, maturity status, and body mass, girls with p-DCD had a much lower energy intake compared to those without p-DCD. Energy intake was similar between boys with and without p-DCD (Figure 4.3.1). Secondly, energy intake was negatively associated with OWOB in p-DCD girls only (Table 4.4.1).

5.1 p-DCD and Energy Intake

No previous studies have looked at energy intake in children with p-DCD. In this study, there was no significant energy intake difference between boys with and without p-DCD. However, girls with p-DCD consumed much less energy than their non-DCD peers. The reason why energy intake was similar in boys and different in girls is currently unknown in the literature. Future studies are needed to investigate reasons why there was a difference in girls, but not boys. Two potential reasons could be body image and under-reporting.

One potential factor that may help to explain the lower reported energy intake in p-DCD girls is body image. Body image is less likely to be related to reporting a reduced energy intake in boys since they may actually report a higher energy intake in attempt to become more muscular (Chang et al., 2011; Tsai et al., 2011; Bardone-Cone et al., 2008). Essentially p-DCD girls could be reporting less energy consumption than their peers

because they dislike the way their body looks (Bosi et al., 2006). This is a euphemism for wanting to lose weight because they think they are too heavy. Since these girls are more inactive than their non-DCD peers (Table 4.1.1), losing weight by reducing their energy intake may be their only option. Dissatisfaction of one's body image is related to restrictive eating practices (Bosi et al., 2006) through disturbed and disordered eating patterns (Bearman et al., 2006; Keel et al., 1997). The literature shows that children with compared to without p-DCD have higher levels of dissatisfied body images and dislikes in their physical appearances (Hay et al., 2001; Piek et al., 2006; Skinner & Piek, 2001; Lingam et al., 2012). A reduction in energy intake in attempt to lose weight affects girls more frequently than boys (Chang et al., 2011; Tsai et al., 2011; Bardone-Cone et al., 2008). The reason for this is a result of the pressures to achieve a 'socially attractive thin' female body (Jones, 2004). Therefore, it is possible that body image could be related to the decreased reported energy intake in p-DCD girls.

Under-reporting could also explain the lower reported energy intake in p-DCD girls. OWOB children are notorious for under-reporting energy intake on self-administrated FFQ, diet records, and diet histories (Gazzangia & Burns, 1993; Johnson-Down et al., 1997; Maffei et al., 1994). They are much more likely to under-report than normal weight children. It is known that p-DCD children are more OWOB than non-DCD children (Cairney et al., 2011; Cairney et al., 2010; Hands & Larkin, 2006; Cantell et al., 2008; Schott et al., 2007). Therefore, p-DCD children are more likely to under-report energy intake than non-DCD children. Girls with the disorder are more likely to under-report than boys with the disorder since they are more OWOB (Tables 4.1.1-2).

Future studies should determine whether or not children with p-DCD are reporting energy intake accurately.

5.2 The Negative Association between Energy Intake and Overweight or Obesity Status

Regardless of p-DCD status, OWOB children reported a lower energy intake than their peers. However, this result shows that OWOB p-DCD children are similar to OWOB non-DCD children in that they both have reported lower energy intakes than their normal weight peers. The association between energy intake and OWOB was similar between p-DCD and non-DCD children since there was no interaction in the logistic regression Model 4. The association between energy intake and OWOB differed by gender (Tables 4.2.1-2 and Table 4.4.1). It is known that increased energy intake leads to OWOB if all factors, such as expenditure, are held constant (Bowman & Vinyard, 2004; McCorry et al., 2002). The negative association between energy intake and OWOB in this present study and previous ones (Skinner et al., 2012; Rocandio et al., 2001; Bandini et al., 1999; Llunch et al., 2000; Tucker et al., 1997; Stewart et al., 1999; Garaulet et al., 2000; Ritchie, 2012; Fabry et al., 1966) is biologically implausible. Therefore, in these studies and this current one, either energy expenditure was not sufficiently measured or energy intake was not accurately measured. This present study is different from others since the Harvard FFQ was used to estimate energy intake and physical inactivity (as a proxy measure of energy expenditure) was controlled. The reason why there was no association in boys while there was a negative one in girls is unknown. Potential reasons for this include: under-reporting, timing of obesity onset, RMR, and energy expenditure.

A common of dietary methodology limitation in large field studies is under-reporting of energy intake. It is more common in OWOB children than normal weight children (Gazzangia & Burns, 1993; Johnson-Down et al., 1997; Maffei et al., 1994). Since girls were more OWOB than boys (Tables 4.1.1-2), girls were more likely to under-report energy intake. Under-reporting could partially explain the negative association found. Future studies are needed to investigate the accuracy of energy intake reporting.

Another potential reason for finding a negative association in cross-sectional studies is the timing of obesity onset (Skinner et al., 2012). In this scenario, some children are OWOB during the time of the study, but they have decided to lower their energy intake prior to the study in attempt to lose weight. This means that although they are currently OWOB, they are truthfully eating less. This may partially explain the negative association found. However, it must be reiterated that it is not biologically possible that a lower energy intake leads to OWOB. Therefore, longitudinal studies are needed to bring resolution to this limitation by tracking energy intake and OWOB over time.

RMR is a huge component of energy expenditure. Although a proxy of energy expenditure was controlled (physical inactivity), RMR was not measured in this study. Only one side of the equation (energy intake) was assessed in this current study. Accounting for RMR in future studies will likely yield different findings since it will fill in a large gap in the energy balance related to OWOB. It is difficult to speculate whether or not p-DCD children have a different RMR than their peers. On one side, p-DCD children could have a higher metabolism than non-DCD children since they are

more OWOB. OWOB children are known to have higher RMR due to a higher amount of muscle mass (Epstein et al., 1989; Yu et al., 2002). There would be no expected BMR differences between boys and girls across obesity groups as there were none in the above studies. On the other side, p-DCD children could have a lower RMR due to lower physical activity levels. Researchers have hypothesized that since physical activity increases muscle mass, it may increase RMR (Goran et al., 1999; Poehlman, 1993; Speakman & Selman, 2003). However, the entire picture of the energy balance must be reviewed, especially the possibility that a change in one component of energy expenditure can result in a compensatory change in other components and changes in energy intake (Goran et al., 1999). Also, the hypothesized increase in RMR depends on several other factors, such as genetics and the activity duration, intensity, type, and frequency. This raises a question of whether or not children with p-DCD have a different RMR than children without the disorder. Furthermore, RMR is essential to the energy balance and should be considered in future studies.

Another reason why the negative association was found could be due to the fact that physical inactivity (a proxy for energy expenditure) overpowered energy intake. It is possible that the higher prevalence of OWOB in children with p-DCD could be primarily due to the decreased energy expenditure (through increased levels of physical inactivity) more so than energy intake. It is known that OWOB children have a higher RMR than normal weight children, but their energy expenditure is lower (Epstein et al., 1989; Yu et al., 2002). Researchers explain that lower physical activity levels among OWOB children explain their lower energy expenditure (Melby et al., 1993). This might be the case for p-DCD children. Maybe p-DCD children are more OWOB than their non-DCD

peers because they are so inactive. Maybe energy intake does not play as large of a role in this population as expected. Future studies are needed to investigate this longitudinally.

Whatever reason is causing the negative association to exist between energy intake and OWOB in this study and others, it must be recognized that is not biologically possible. An increased energy intake leads to OWOB when all factors, such as energy expenditure, are constant. Future studies should use longitudinal methods to rule out the possibility of the timing of obesity onset. Other studies should also determine the accuracy of energy intake reporting from the Harvard FFQ. It is also important that future studies assess RMR since it is the largest part of energy expenditure and will give a more comprehensive picture of the association between energy intake and OWOB.

5.3 Study Limitations and Strengths

5.3.1 Cross-Sectional Design Limitation

All the findings of this study should be interpreted in terms of these limitations. The cross-sectional design does not allow for any causal links to be made. For example, since a negative association between energy intake and OWOB was found in girls, it is not valid to say that eating less will lead to a higher body mass.

5.3.2 Prevalence

The prevalence of p-DCD in this study was 6.0% which is very similar to the Canadian prevalence reported by Gibbs, Appleton, & Appleton (2007). However, the prevalence was 4.8% in males and 9.3% in females, which is different from most studies

reporting the prevalence to be much greater in boys than girls (Lingam et al., 2009; American Psychiatric Association, 2000). This result may have been due to the fact that p-DCD status classification was not gender adjusted, and boys have higher BOTMP-SF scores than girls. However, this classification of p-DCD status was not gender adjusted in several previous studies using the same data.

5.3.3 Variable Measurement

Another potential problem was the lack of available information on ethnicity which is known to be associated with OWOB. Non-Caucasian children tend to be more obese than Caucasian children (Caprio et al., 2008). However, this may not be such a major limitation as children in the Niagara region are predominantly Caucasian.

Since Tanner stage variables were unavailable for this large population study, APHV was used as a proxy measure of maturity instead. Although it is correlated to Tanner stages (Val Abbassi, 1998; Tanner & Whitehouse, 1976), it is not the best tool to assess maturity since the assessment of sitting height may not have been measured accurately. Sitting height was subtracted from standing height in the PHAST study, and so leg length is likely to be under-estimated due to gluteal fat. This bias is likely to under-estimate the maturity using APHV in p-DCD girls the most since they have the highest mean BMI.

The measurement of energy intake was subject to self-report bias since overweight and obese children are notorious for under-reporting their EI (Bandini, Must, Cyr, Goldberg, & Dietz, 1999; Johnson-Down, O'Loughlin, Koski, & Gray-Donald, 1997). These children tend to lie about what they consume due to feelings of self-

consciousness and thinking there are ‘fat’ compared to normal weight peers. Under-reporting among these children could offer some explanation for the negative association between energy intake and body mass in this study (Gazzangia & Burns, 1993). On the other side, it is also possible that OWOB children could truthfully be eating less in attempt to lose weight (Skinner et al., 2012). Also since boys tend to be less conscious about reporting food and beverage consumption than girls, the accuracy of energy intake among them could be reduced making the energy intake – body mass association closer to the null. On the other hand, the self-reported Harvard FFQ has been validated (Longnecker et al., 1993; Willett et al., 1985; Hernandez-Aliva, Romieu, Parra, Hernandez-Aliva, Madrigal, & Willitt, 1998). Furthermore, the FFQ is an appropriate tool to ascertain energy intake data for this particular study.

BMI is not the best way to categorize OWOB in children since it does not measure adiposity. However, BMI has been validated and used in many published studies to categorize OWOB (Cole et al., 2000). It has been highly correlated ($\rho=0.813$) to body fat percentage measured by whole body air displacement plethysmography in a study using PHAST data (Chirico et al., 2011). In addition to BMI, WC was used in this study. The results using WC were similar to using BMI. Further, Reilly, Dorosty, Ghomizadeh, Sherriff, Wells, & Ness (2010) found that WC was similar to BMI in detecting body fat in children. Overall, the use of BMI is appropriate for the design of this study since it is more feasible compared to other timely, expensive tools, such as hydrostatic weighing.

5.3.4 Strengths

There were several strengths in this study. The novelty of this study is important to the body of DCD literature, such that this is the first study to address energy intake in this population. This same dataset was also used by Cairney et al. (2009a). This adds confidence to this current study since these authors found a high positive predictive value for the BOTMF-SF. Also, in this study, confounding factors, such as physical inactivity, were controlled in the analysis. Controlling physical inactivity and others is important to the validity of the study. The use of published cut-offs in previous studies for classifying p-DCD and body mass status (normal weight vs. overweight or obese) is another strength.

5.4 Future Directions

Future studies should investigate why reported energy intake was lower for p-DCD girls compared to their peers, while there was no difference in boys. Future studies also need to investigate why there was a negative association between energy intake and OWOB in this population only in girls. The next step is to design a longitudinal study to investigate the impact (role) of energy intake in the relationship between p-DCD and OWOB.

5.5 Conclusion

No previous research has reported the association between energy intake and OWOB in children with p-DCD. Girls with compared to without p-DCD have a lower energy intake, whereas energy intake is similar in boys regardless of p-DCD status. Both girls and boys with p-DCD are more physically inactive and had a higher BMI compared to their peers (see Table 4.1.1-2). It is known that OWOB requires a positive energy

balance. Since there is no energy intake difference in boys with compared to without p-DCD and p-DCD girls are actually consuming less than their peers, then perhaps the reason for their higher prevalence of OWOB is resulting primarily from the increased physical inactivity. The clinical implication for treating children with DCD here would be to focus on targeting interventions that increase physical activity, rather than restricting energy intake.

References

- Albertsson-Wikland, K., Rosberg, S., Lannering, B., Dunkel, L., Selstam, G., & Norjavaara, E. (1997). Twenty-four-hour profiles of luteinizing hormone folliclestimulating hormone, testosterone, and estradiol levels: a semilongitudinal study throughout puberty in healthy boys. *J Clin Endocrinol Metab*, 82, 541–549.
- American Psychiatric Association. (1994). *DSM-IV Diagnostic and Statistical Manual of Mental Disorders*. Washington, DC: American Psychiatric Association.
- (2000). *DSM-IV-TR Diagnostic and Statistical Manual of Mental Disorders*. Washington, DC.
- American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (Fifth ed.). Arlington, VA: American Psychiatric Publishing. pp. 747.
- Bandini, L.G., Vu, D., Must, A., Cyr, H., Goldberg, A., & Dietz, W.H. (1999). Comparison of high-calorie, low-nutrient-dense food consumption among obese and non-obese adolescents. *Obes Res* 1999, 7, 438-43.
- Bardone-Cone, A.M., Joiner, T.E., Crosby, R.D., Crow, S.J., Klien, M.H., le Grange, D., ... Wonderlich, S.A. (2008). Examining a psychosocial interactive model of binge eating and vomiting in women with bulimia nervosa and subthreshold bulimia nervosa. *Beh Res Therapy*, 46, 887-894.
- Barlow, S. E., & Dietz, W. H. (1998). Obesity evaluation and treatment: expert committee recommendations. The Maternal and Child Health Bureau, Health Resources and Services Administration, and the Department of Health and Human Services. *Pediatrics*, 102, 29.

- Barnett, L., M., van Beurden, E., Morgan, P. J., Brooks, L. O., Beard, J. R. (2009). Childhood motor skill proficiency as a predictor of adolescent physical activity. *Journal of Adolescent Health, 44*, 252-259.
- Bearman, S.K., Martinez, E., & Stice, E. (2006). The skinny on body dissatisfaction: a longitudinal study of adolescent girls and boys. *J Youth Adolesc, 35*(2), 217-229.
- Belfort, C.A., Nazir, N., & Perri, M.G. (2012). Prevalence of obesity among adults from rural and urban areas of the united states: findings from NHANES (2005-2008). *Journal of Rural Health, 28*(4), 392-397.
- Beunen, G., Malina, R.M., Lefevre, J., Claessens, A.L., Renson, R., Simons J., ...Lysens, R. (1994). Size, fatness and relative fat distribution of males of contrasting maturity status during adolescence and as adults. *Int J Obes Relat Metab Disord, 18*, 670 –678.
- Bhuiyan, M. U., Zaman, S., & Ahmed, T. (2013). Risk factors associated with overweight and obesity among urban school children and adolescents in Bangladesh: a case-control study. *BMC Pediatrics, 13*, 72.
- Biddle, S. J., Gorely, T., & Stensel, D. J. (2004). Health-enhancing physical activity and sedentary behaviour in children and adolescents. *Journal of Sports Sciences, 22*, 679-701.
- Bitar, A., Vernet, J., Coudert, J., & Vermorel, M. (2000). Longitudinal changes in body composition, physical capacities and energy expenditure in boys and girls during the onset of puberty. *Eur J Nutr, 39*, 157–163.
- Blank, R., Smits-Engelsman, B., Polatajko, H., & Wilson, P. (2012). European

- Academy for Childhood Disability (EACD): recommendations on the definition, diagnosis and intervention for developmental coordination disorder (long version). *Dev Med Child Neurol*, 54(1), 54-93.
- Booth, M., Okely, A. D., Chey, T., & Bauman, A. (2002). The reliability and validity of the Adolescent Physical Activity Recall Questionnaire. *Medicine & Science in Sports and Exercise*, 34, 1986-1995.
- Booth, M.L., Okely, A.D., Chey, T., Bauman, A.E., & Macaskill, P. (2009). Epidemiology of physical activity participation among New South Wales school students. *Australian and New Zealand Journal of Public Health*, 26(4), 371-374.
- Bosi, M.L.M., Luiz, R.R., Morgado, C.M.C., Costa, M.L.S., & Carvalho, R.J. (2006). Auto-percepção da imagem corporal entre estudantes de nutrição no Rio de Janeiro. *J Bras Psiquiatr*, 55(1), 34-40.
- Bowman, S. A., & Vinyard, B. T. (2004). Fast food consumption of U.S. adults: Impact of energy and nutrient intakes and overweight status. *J Am Coll Nutr*, 23(2), 163-168.
- Brambilla, P., Bedogni, G., Moreno, L. A., Goran, M. I., Gutin, B., Fox, K. R., ... & Pietrobelli, A. (2006). Crossvalidation of anthropometry against magnetic resonance imaging for the assessment of visceral and subcutaneous adipose tissue in children. *International Journal of Obesity*, 30(1), 23-30.
- Bridger, T. (2009). Childhood obesity and cardiovascular disease. *Paediatr Child Health*, 14(3), 177-182.
- Bruininks, R.H. *Bruininks-Oseretsky test of motor proficiency: examiner's manual*. American Guidance Service: Circle Pines, MN, 1978.

- Bruner, M.W., Lawson, J., Pickett, W., Boyce, W., & Janssen, I. (2008). Rural Canadian adolescents are more likely to be obese compared with urban adolescents. *International Journal of Pediatric Obesity* 2008, 3(4), 205-211.
- Cairney, J., Hay, J., Fought, B. E., Corna, L. M., & Flouris, A. (2006). Developmental coordination disorder, age, play: A test of the divergence in activity-deficit with age hypothesis. *Adapted Physical Activity Quarterly*, 23, 261-276.
- Cairney, J., Hay, J., Fought, B. E., & Hawes, R. (2005b). Developmental coordination disorder and overweight and obesity in children aged 9-14 y. *International Journal of Obesity*, 29, 369-372.
- Cairney, J., Hay, J., Fought, B., Mandigo, J., & Flouris, A. (2005a). Developmental coordination disorder, self-efficacy toward physical activity, and play: Does gender matter? *Adapted Physical activity Quarterly*, 22, 67-82.
- Cairney, J., Hay, J. A., Fought, B. E., Wade, T. J., Corna, L., & Flouris, A. (2005b). Developmental coordination disorder, generalized self-efficacy toward physical activity, and participation in organized and free play activities. *The Journal of Pediatrics*, 147, 515-520.
- Cairney, J., Hay, J. A., Mandigo, J., Wade, T. J., Fought, B. E., & Flouris, A. (2007). Developmental coordination disorder and reported enjoyment of physical education in children. *European Physical Education Review*, 13(1), 81-98.
- Cairney, J., Hay, J., Veldhuizen, S., & Fought, B. (2011). Assessment of body composition using whole body air-displacement plethysmography in children with and without developmental coordination disorder. *Research in Developmental Disabilities*, 32, 830-835.

- Cairney, J., Hay, J. A., Veldhuizen, S., Missiuna, C., & Fought, B. E. (2009a). Comparing probable case identification of developmental coordination disorder using the short form of the Bruininks-Oseretsky Test of Motor Proficiency and the Movement ABC. *Child Care Health Dev*, 35(3), 402-408.
- Cairney, J., Hay, J. A., Veldhuizen, S., Missiuna, C., & Fought, B. E. (2009b). Developmental coordination disorder, sex, and activity deficit over time: A longitudinal analysis of participation trajectories in children with and without motor coordination difficulties. *Dev Med Child Neurol*, 52(3), 67-72.
- Cairney, J., Hay, J., Veldhuizen, S., Missiuna, C., Mahlberg, N., & Fought, B. E. (2010). Trajectories of relative weight and waist circumference among children with and without developmental coordination disorder. *CMAJ*, 182(11), 1167-1172.
- Cairney, J., Hay, J., Wade, T., Fought, B. E., & Flouris, A. (2007). Developmental coordination disorder and reported enjoyment in physical education in children. *European Physical Education Review*, 13(1), 81-98.
- Cairney, J., Missiuna, C., Veldhuizen, S., & Wilson, B. (2008). Evaluation of the psychometric properties of the developmental coordination questionnaire for parents (DCD-Q): Results from a community based study of school-aged children. *Human Movement Science*, 27(6), 932-940.
- Cairney, J., Veldhuizen, S., Kurdyak, P., Missiuna, C., Fought, B. E., & Hay, J. A. (2007). Evaluating the CSAPPA sub-scales as potential screening instruments for developmental coordination disorder. *Archives of Disease in Childhood*, 92(11), 987-991.
- Cantell, M. H., Smyth, M. M., & Ahonen, T. P. (1994). Clumsiness in adolescence:

- Educational, motor, and social outcomes of motor delay detected at 5 years. *Adapted Physical Activity Quarterly*, 11, 115-129.
- Caprio, S., Daniels, S.R, Drewnowski, A., Kaufman, F.R., Palinkas, L.A, Rosenbloom, A.L, & Schwimmer, J.B. (2008). Influence of race, ethnicity, and culture on childhood obesity: implications for prevention and treatment. *Diabetes care*, 31(11), 2211-2221.
- Castelli, D. M., & Valley, J. A. (2007). Chapter 3: The relationship of physical fitness and motor competence to physical activity. *Journal of Teaching in Physical Education*, 26, 358-374.
- Causgrove Dunn, J, & Dunn, J. G. H. (2006). Psychosocial determinants of physical education behavior in children with movement difficulties. *Adapted Physical Activity Quarterly*, 23, 293-309.
- Cermak, S., & Larkin, D. (Eds). (2002). *Developmental coordination disorder*. Albany, NY: Delmar.
- Chang, Y.J., Lin, W., & Wong, Y. (2011). Survey on eating disordered-related thoughts, behaviors, and their relationships with food intake and nutritional status in female high school students in Taiwan. *J Am Coll Nutr*, 30(1): 39-48.
- Chirico, D., O'Leary, D., Cairney, J., Klentrou, P., Haluka, K., Hay, J., Faught, B. (2010). Left ventricular structure and function in children with and without developmental coordination disorder. *Research in Developmental Disabilities*, 32, 115-123.
- Colley, R. C, Garriguet, D., Janssen I., Criag, C. L., Clarke, J., & Tremblay, M. S.

- (2011). Physical activity of Canadian children and youth: Accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. *Health Reports*, 22(1), 15-23.
- Cole, T. J., Bellizzi, M. C., Flegal, K. M., & Dietz, W. H. (2000). Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*, 320, 1240-1243.
- Cutler, D.M., Glaeser, E.L., & Shapiro, J.M. (2003). Why have Americans become more obese? *J Econ Perspect*, 17, 93-118.
- Daniels, S.R., Arnett, D.K., Eckel, R.H., Gidding, S.S., Hayman, L.L., Kumaniiika, S., ... Williams, C.L. (2005). Overweight in children and adolescents: pathophysiology, consequences, prevention and treatment. *Circulation*, 111(15), 1999-2012.
- Danner, F.W. (2008). A national longitudinal study of the association between hours of TV viewing and the trajectory of BMI growth among US children. *J Pediatr Psychol*, 33, 1100-1107.
- Dixon, A. K. (1983). Abdominal fat assessed by computed tomography: sex difference in distribution. *Clinical Radiology*, 34, 189-191.
- Dupré, E. (1925). *Pathologie de L'Imagination et de L'Emotivite*. Paris, Pavot.
- Dunford, C., Missiuna, C., Street, E., & Sibert, J. (2005). Children's perceptions of the impact of developmental coordination disorder on activities of daily living. *British Journal of Occupational Therapy*, 68(5), 207-214.
- Epstein, L.H., Wing, R.R., Cluss, P., Fernstrom, M.H., Penner, B., Perkins, K.A., ...

- Valoski, A. (1989). Resting metabolic rate in lean and obese children: relationship to child and parent weight and percent overweight change. *Am J Clin Nutr*, 49, 331-336.
- Fa'brý, P., Hejda, S., Cerný, K., Osancová, K., & Pechar, J. (1966). Effect of meal frequency in schoolchildren: changes in weight-height proportion and skinfold thickness. *Am J Clin Nutr*, 18, 358-361.
- Fanelli, M. T., & Kurczmarski, R. J. (1984). Ultrasound as an approach to assessing body composition. *American Journal of Clinical Nutrition*, 39, 703-709.
- Faught, B. E., Hay, J. A., Cairney, J., & Flouris, A. (2005). Increased risk for coronary vascular disease in children with developmental coordination disorder. *Journal of Adolescent Health*, 37, 376-380.
- Fisher, A., Reilly, J. J., Kelly, L. A., Montgomery, C., Williamson, A., Paton, J. Y., & Grant, S. (2005). Fundamental movement skills and habitual physical activity in young children. *Medicine & Science in Sports & Exercise*, 37(4), 684-688.
- Flodmark, C.E., Lissau, I., Moreno, L.A., Pietrobelli, A., & Widhalm, K. (2004). New insights into the field of children and adolescents' obesity: the European perspective. *International Journal of Obesity*, 28(1), 1189-1196.
- Ford, F. R. (1966). *Disease of the nervous system in infancy, childhood and adolescence* (5th ed.). Springfield, IL: Charles C. Thomas.
- Fox, K., Peters, D, Armstrong, N., Sharpe, P., & Bell, M. (1993). Abdominal fat deposition in 11-year-old children. *International Journal of Obesity*, 17, 11-16.
- Freedman, D. S., Khan, L. K., Dietz, W. H., Srinivasan, S. R., & Berenson, G. S. (2001)

- Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study. *Pediatrics*, 208, 712–718.
- Fulton, J.E., Dai, S., Steffen, L.M., Grunbaum, J.A., Shah, S.M., & Labarthe, D.R. (2009). Physical activity, energy intake, sedentary behavior, and adiposity in youth. *Am J Prev Med*, 37, S40–S49.
- Keel, P.K., Fulkerson, J.A., & Leon, G.R. (1997). Disordered eating precursors in pre- and early adolescent girls and boys. *Journal of Youth and Adolescence*, 26, 203–216.
- Gaines, R., Missiuna, C., Egan, M., & McLean, J. (2008). Educational outreach and collaborative care enhances physician’s perceived knowledge about developmental coordination disorder. *BMC Health Serv Res*, 8, 21.
- Garazhyan, S., Raftari, H., Zamani, M., Piri, E., Rakhshanizadeh, A., & Peeri, M. (2013). The effects of heredity on the body composition and cardiorespiratory fitness of parents and children. *Annals of Biological Research*, 4(3), 41-45.
- Gazzaniga, J. M., & Burns, T. L. (1993). Relationship between diet composition and body fatness, with adjustment for resting energy expenditure and physical activity, in preadolescent children. *Am J Clin Nutr*, 58, 21-28.
- Geschwind, N. (1975). “The apraxias: Neural mechanisms of disorders of learned movements.” *American Scientist*, 63, 188-195
- Gibbs, J., Appleton, J., & Appleton, R. (2007). Dyspraxia or developmental coordination disorder: Unraveling the enigma. *Archives of Disease in Childhood*, 92, 534-539.
- Gnavi, R., Spagnoli, T.D., Galotto, C., Pugliese, E., Carta, A., & Cesari, L. (2000).

- Socioeconomic status, overweight and obesity in prepuberal children: a study in an area of Northern Italy. *Eur J Epidemiol*, 16(9), 797-803.
- Godin, G., & Shepard, R. J. (1985). A simple method to assess exercise behavior in the community. *Canadian Journal of Applied Sports Sciences*, 10, 141-146.
- Goran, M. I., Kaskoun, M. C., & Shuman, W. P. (1995). Intraabdominal adipose tissue in young children. *International Journal of Obesity*, 19, 279-283.
- Goran, M.I., Reynolds, K.D., & Lindquist, C.H. (1999). Role of physical activity in the presentation of obesity in children. *International Journal of Obesity*, 23(3), S18 S33.
- Gower B.A., Nagy, T.R., Goran, M.I. (1999). Visceral fat, insulin sensitivity, and lipids in prepubertal children. *Diabetes*, 48, 1515–1521.
- Green, D, & Wilson, N. B. (2008). The importance of parent and child opinion in detecting change in movement capabilities. *Canadian Journal of Occupational Therapy*, 75(4), 208-219.
- Gueze, R. H. (2007). Developmental coordination disorder: A review of current approaches. Marseille, France: Solal.
- Guo, S. S., & Chumlea, W. C. (1999). Tracking of body mass index in children in relation to overweight in adulthood. *American Journal of Clinical Nutrition*, 70, 145-148.
- Gwynne, K., & Blick, B. (2004). Motor performance checklist for 5-year-olds: a tool for identifying children at risk of developmental co-ordination disorder. *J Paediatric Child Health*, 40(7), 369-373.
- Hands, B., & Larkin, D. (2006). Physical fitness differences in children with and

- without motor learning difficulties. *European Journal of Special Needs Education*, 21(4), 447-456.
- Harter, S. (1982). The Perceived Competence Scale for Children. *Child Development*, 53(1), 87-97.
- Hay, J. (1992). Adequacy in and predilection for physical activity in children. *Clinical \ Journal of Sports Medicine*, 2, 192-201.
- Hay, J. (1996). Predicting the selection of physical education class in grade ten from self-perceptions reported in grades seven, eight, and nine. *Brock Education*, 659–569.
- Hay, J. (1999). Benefits of physical activity of integrating learning disabled children into the classroom. *Pediatric Exercise Science*, 11, 273.
- Hay, J. & Donnelly, P. (1996). Sorting out the boys from the girls: teacher and student perceptions of student physical ability. *Avante*, 2, 36-52.
- Hay, J.A., Hawes, R., Faight, B.E. (2004). Evaluation of a screening instrument for developmental coordination disorder. *J Adolesc Health*, 34308–313.313.
- Hay, J., & Missiuna, C. (1998). Motor proficiency in children reporting low levels of participation in physical activity. *Canadian Journal of Occupational Therapy*, 65(2), 64-71.
- Hay, J., Hawes, R., & Faight, B.E. 2004. Evaluation of a screening instrument for developmental coordination disorder. *J Adolec Health*, 34, 308-313.
- Hay, J.A., Hawes, R., Faight, B.E., Cairney, J., & Klentrou, N. (2001). Gender differences in satisfaction with body appearance as a function of body fat, aerobic fitness, activity levels, and self-efficacy. *Pediatric Exercise Science*, 13(3), 279.

- Haymes, E. M., Lundergen, H. M., Loomis, J. L., & Buskirk, E. R. (1976). Validity of \ the ultrasonic technique as a method of measuring subcutaneous tissue. *Annals of Human Biology*, 3, 245-251.
- Henderson, S. E. & Sugden, D. A. Movement assessment battery for children. San Antonio Texas, USA.: Psychological Cooperation; 1992.
- Henderson, S. E. & Sugden, D. A. (2007). *Movement Assessment Battery for Children*. Second Edition. London, The Psychological Corporation.
- Herman, K. M., Craig, C. L., Guavin, L., & Katzmarzyk, P. T. (2009). Tracking of obesity and physical activity from childhood to adulthood: The Physical Activity Longitudinal Study. *International Journal of Pediatric Obesity*, 4(4), 281-288.
- Hernandez-Aliva, M., Romieu, I., Parra, S., Hernandez-Aliva, J., Madrigal, H., & Willitt, W. (1998). Validity and reproducibility of a food frequency questionnaire to assess dietary intake of women living in Mexico City. *Salud pública de México*, 39(40), 133-140.
- Hill, R., & Davies, P. (2001). The validity of self-reported energy intake as determined using doubly labeled water technique. *Br J Nutr*, 85,415–430.
- Himes, E. M., Roche, A. F., & Siervogel, R. M. (1979). Compressibility of skinfolds and the measurement of subcutaneous fatness. *American Journal of Clinical Nutrition*, 32, 1734-1740.
- Hodgkin, E., Hamlin, M.J., Ross, J.J., & Peters, F. (2010). Obesity, energy intake and physical activity in rural and urban New Zealand children. *Rural Remote Health*, 10(2), 1336.
- Hoffman, D.J., Sawaya, A.L., Coward, W.A., Wright, A., Martins, P.A., de Nascimento,

- C., ...Roberts, S.B. (2000). Energy expenditure of stunted and nonstunted boys and girls living in the shantytowns of Sao Paulo, Brazil. *Am J Clin Nutr*, 72(4), 1025-1031.
- Hu, F. B., Manson, J., Stampfer, M., Graham C., Liu, S., Solomon, C. G., & Willett, W. C. (2001). Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. *The New England Journal of Medicine*, 345(11), 790–797.
- Huang, T.T., Johnson, M.S., Figueroa, R., Dwyer, J.H., & Goran, M. (2001). Growth of visceral fat, subcutaneous abdominal fat, and total body fat in children. *Obesity Research*, 9(5), 283-289.
- Jago R, Baranowski T, & Yoo S. (2004). Relationship between physical activity and diet among African-American girls. *Obes Res*, 12S, 55S– 63S.
- Jarus, T., Lourie-Gelberg, Y., Engel-Yeger, B., & Bart, O. (2011). Participation patterns of school-aged children with and without DCD. *Research in Developmental Disabilities*, 32, 1323-1331.
- Jolliffe, D. (2004). Extent of overweight among US children and adolescents from 1971-2000. *Int J Obes*, 28, 4-9.
- Johnson-Down, L., O'Loughlin, J., Koski, K. G., & Gray-Donald, K. (1997). High prevalence of obesity in low income and multiethnic schoolchildren: A diet and physical activity assessment. *The Journal of Nutrition*, 127(12), 2310-2315.
- Jones, D.C. (2004). Body image among adolescent girls and boys: A longitudinal study. *Developmental Psychology*, 40, 823–835.
- Kasesjo, B, & Gillberg, C. (1999). Developmental coordination disorder in Swedish 7-

- year-old children. *Journal of the American Academy of Child and Adolescent Psychiatry*, 38, 820-828.
- Keshteli, A.H., Esmailzadeh, A., Rajaie, S., Askari, G., Feinle-Bisset, C., & Adibi, P. (2014). A dish-based semi-quantitative food frequency questionnaire for assessment of dietary intakes in epidemiologic studies in Iran: design and experiment. *Int J Prev Med*, 5(1), 29-36.
- Keskitalo, K., Tuorila, H., & Spector, T.D. (2008). The Three-Factor Eating Questionnaire, body mass index, and responses to sweet and salty fatty foods: a twin study of genetic and environmental associations. *Am J Clin Nutr*, 88, 263–271.
- Kindblom, J.M., Lorentzon, M., Norjavaara, E., Lönn, E., Brandberg, J., Angelhed, J., Hellqvist, A, ... Ohlsson, C. (2006). Pubertal timing Is an independent predictor of central Adiposity in young adult males.The Gothenburg Osteoporosis and Obesity Determinants Study.*Diabetes*, 55(11), 3047-3052.
- Kirby, A., Salmon, G., & Edwards, L. (2007). Attention Deficit Hyperactivity Disorder and developmental co-ordination difficulties: knowledge and practice among child and adolescent psychiatrists and paediatricians. *Psychiatric Bulletin*, 31, 336-338.
- Kirby, A., Sugden, D., Beveridge, S. & Edwards, L. (2008). Developmental Co-ordination Disorder (DCD) in adults and adolescents. *Journal of Research in Special Education Needs*, 8, 120-31.
- Klein-Platat, C., Wagner, A., Haan, M.C., Arveiler, D., Schlienger, J.L., & Simon, C.

- (2003). Prevalence and sociodemographic determinants of overweight in young French adolescents. *Diabetes/Metabolism Research Reviews*, 19(2), 153-158.
- Klentrou, P., Hay, J., & Plyly, M. (2003). Habitual physical activity levels and health outcomes of Ontario youth. *European Journal of Applied Physiology*, 89(5), 460-465.
- Larkin, D. & Rose, E. (2005). Assessment of developmental coordination disorder. In: *Children with Developmental Coordination Disorder* (eds D. Sugden & M. Chambers), pp. 135-154. Whurr Publishers, London, UK.
- de Lauzon-Guillain, B., Basdevant, A., & Romon, M. (2006). Is restrained eating a risk factor for weight gain in a general population? *Am J Clin Nutr*, 83, 132–138.
- Lavie, C.J., Milani, R.V., & Ventura, H.O. (2009). Obesity and cardiovascular disease: risk factor, paradox, and impact on weight loss. *Cardiology*, 53(1), 1925-1932.
- Lazarus, R., Baur, L., Webb, K., & Blyth, F. (1996). Body mass index in screening for adiposity in children and adolescents: systematic evaluation using receiver operating characteristic curves. *Am J Clin Nutr*, 63, 500-506.
- Lee, A., Hankin, B.L., & Mermelstein, R.J. (2010). Perceived social competence, negative social interactions, and negative cognitive style predict depressive symptoms during . *J Clin Child Adolesc Psychol*, 39(5), 603-615.
- Lefebvre, C. & Reid, G. (1998). Prediction in ball catching by children with and without a development co-ordination disorder. *Adapted Physical Activity Quarterly*, 15, 299-315.

- Lichtenstein, P., Carlstrom, E., Rastam, M., Gillberg, C., & Anckarsater, H. (2010). The genetics of autism spectrum disorders and related neuropsychiatric disorders in childhood. *American Journal of Psychiatry*, 167(11), 1357–1363.
- Lingam, R., Golding, J., Johnmans, M.J., Ellis, M., & Edmond, A. (2010). The association between developmental coordination disorder and other developmental traits. *Pediatrics*, 126, e1109-e1118.
- Lingam, R., Hunt, L., Golding, J., Jongmans, M., & Emond, A. (2009). Prevalence of developmental coordination disorder using the DSM-IV at 7 years of age: A UK population-based study. *Pediatrics*, 123(4), 693-700.
- Lingam, R., Jongmans, M.J., Ellis, M., Hunt, L.P., Golding, J., & Emond, A. (2012). Mental health difficulties in children with developmental coordination disorder. *Pediatrics*, 129, 882-891.
- Liu, J., Akseer, N., Faight, B. E., Cairney, J., & Hay, J. (2012). Use of leg length to height ratio to assess the risk of childhood overweight and obesity: Results from a longitudinal cohort study. *Annals of Epidemiology*, 22(2), 120-125.
- Liu, J., Bennett, K.J., Harun, N., & Probst, J.C. (2008). Urban-rural differences in overweight status and physical inactivity among US children aged 10-17 years. *J Rural Health*, 24(4), 407-415.
- Lluch, A., Herbeth, B., Mejean, L., & Siest, G. (2000). Dietary intakes, eating style and overweight in the Stanislas Family Study. *International Journal of Obesity*, 24, 1493-1499.
- Longnecker, M.P., Lissner, L., Holden, J.M., Flack, V.F., Taylor, P.R., Stampfer, M.J., & Willett, W.C. (1993). The Reproducibility and Validity of a Self- Administered

- Semiquantitative Food Frequency Questionnaire in Subjects from South Dakota and Wyoming. *Epidemiology*, 4, 356-365
- Lundy-Ekman, L., Ivry, R. B., Keele, S., & Woollacott, M. (1991). Timing and force control deficits in clumsy children. *Journal of Cognitive Neuroscience*, 3, 367-376.
- Maffeis, C., Schutz, Y., Zaffanello, M., Piccoli, R., & Pinelli, L. (1994). Elevated energy expenditure and reduced energy intake in obese prepubertal children: paradox of poor dietary reliability in obesity? *J Pediatr*, 124, 348-354.
- Maffeis, C., Zaffanello, M., Pinelli, L., Schutz, Y. (1996). Total energy expenditure and patterns of activity in 8-10-year-old obese and nonobese children. *J Pediatr Gastroenterol Nutr*, 23, 256-261.
- Magalhaes, L. C., Cardoso, A. A., & Missiuna, C. (2011). Activities and participation in children with developmental coordination disorder: A systematic review. *Research in Developmental Disabilities*, 32, 1309-1316.
- Magarey, A.M., Daniels, L.A., Boulton, T.J., & Cockington, R.A. (2001). Does fat intake predict adiposity in healthy children and adolescents aged 2—15 y? A longitudinal analysis. *Eur J Clin Nutr*, 55(6), 471-481.
- Malina, R.M., & Bouchart, C. (1991). Growth maturation and physical activity. Human Kinetics Books, Champaign, Illinois, pp 92–149.
- Matheson, D.M., Killen, J.D., Wang, Y., Varady, A., & Robinson, T.N. (2004). Children's food consumption during television viewing. *Am J Clin Nutr*, 79, 1088–1094.
- Maynard, L. M., Wisemandle, W., Roche, A. F., Chumlea, W. C., Guo, S. S., Siervogel,

- R. M. (2001). Childhood body composition in relation to body mass index. *Pediatrics*, 107, 344-350.
- McCorey, M.A., Suen, V.M., & Roberts, S.B. (2002). Biobehavioural influences on energy intake and adult weight gain. *J Nutr*, 132(12), 380-384.
- Melby, C., Scholl, C., Edwards, G., & Bullough, R.. (1993). Effect of acute resistance exercise on postexercise energy expenditure and resting metabolic rate. *J Appl Physiol*, 75, 1847-1853.
- Miller, L. T., Missuina, C. A., McNab, J. J., Malloy-Miller, T., & Polatajko, H. J. (2001). Clinical description of the children with developmental coordination disorder. *Canadian Journal of Occupational Therapy*, 68, 5-15.
- Mirwald, R.L., Baxter-Jones, A.D.G., Bailey, D.A., & Beunen, G.P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise*, 34(4), 689-694.
- Missiuna, C., Cairney, J., Pollock, N., Russell, D., Macdonald, K., Cousins, M., ... Schmidt, L. (2011). A staged approach for identifying children with developmental coordination disorder from the population. *Research in Developmental Disabilities*, 32, 549-559.
- Missiuna, C., Law, M., King, S., & King, G. (2006). Mysteries and mazes: parents' experiences of children with developmental coordination disorder. *Can J Occup Ther*, 73, 7-17.
- Missiuna, C., Moll, S., King, S., King, G., & Law, M. (2007). A trajectory of troubles: parents' impressions of the impact of developmental coordination disorder. *Phys Occup Ther Pediatr*, 27, 81-101.

- Missiuna, C., Rivard, L., & Bartlett, D. (2006). Exploring assessment tools and the target of intervention for children with developmental coordination disorder. *Phys Occup Ther Pediatr*, 26(1-2), 71-89.
- Must, A. & Tybor, D.J. (2005). Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth. *Int J Obes (Lond)*, 29(2S), S84 –96.
- Neovius, M., Linne, Y., & Rossner, S. (2005). BMI, waist-circumference and waist-hip-ratio as diagnostic tests for fatness in adolescents. *International Journal of Obesity*, 29(2), 163-169.
- Okely, A. D., Booth, M. L., & Patterson, J. W. (2001). Relationship of physical activity to fundamental movement skills among adolescents. *Medicine & Science in Sports & Exercise*, 33(11), 1899-1904.
- Olivardia, R. Body image and muscularity. In: Cash TF, Pruzinsky T, eds. *Body image: a handbook of theory, research, and clinical practice*. New York: Guilford Press, 2002:210–18.
- Olsen, S. F., Halldorsson, T. L., Willett, W. C., Knudsen, V. K., Gillman, M. W., ...& Olsen, J. (2007). *American Journal of Clinical Nutrition*, 86, 1104-1110.
- Orton, S. T. (1937). *Reading, Writing and Speech Problems In Children*. New York, W. W. Norton.
- Parsons, T.J., Power, C., Logan, S., & Summerbell, C.D. (1999). Childhood predictors of adult obesity: a systematic review. *Int J Obes*, 23(8):S1-S107.
- Patterson, P. D., Moore, C. G., Probst, J. C., & Shinogle, J. A. (2004). Obesity and physical activity in rural American. *J Rural Health*, 20(2), 151-159.

- Pearsall-Jones, J. G., Piek, J. P., Rigoli, D., Martin, N. C., & Levy, F. (2009). An investigation into etiological pathways of DCD and ADHD using a monozygotic twin design. *Twin Research & Human Genetics*, 12(4), 381–391.
- Piek, J.P., Baynam, G.B., & Barrett, N.C. (2006). The relationship between fine and gross motor ability, self-perceptions and self-worth in children and adolescents. *Hum Mov Sci*, 25(1), 65-75.
- Pietiläinen, K.H., Kaprio, J., Borg, P., Plasqui, G., Yki-Järvinen, H., Kujala, U.M., Rose, R.J., ... Rissanen, A. (2008). Physical inactivity and obesity: a vicious circle. *Obesity*, 16(2), 409-414.
- Plotnikoff, R. C., Bercovitz, K., & Loucaides, C. A. (2004). Physical activity, smoking, and obesity among Canadian school youth. Comparison between urban and rural school. *Canadian Journal of Public Health*, 95(6), 413-418.
- Poehlman, E.T. (1989). A review: exercise and its influence on resting energy metabolism in man. *Med Sci Sport Exer* 1989; 21, 515-525.
- Polatajko, H. J. & Cantin, N. (2005). Developmental Coordination Disorder (Dyspraxia): An Overview of the State of the Art. *Seminar Pediatric*, 12, 250-258.
- Poulsen, A.A. & Ziviani, J.M. (2004). Can I play too? Physical activity engagement of children with developmental coordination disorders. *Canadian Journal of Occupational Therapy*, 71(2), 100-108.
- Poulsen, A.A., Ziviani, J.M., & Cuskelly, M. (2008). Lesiure time physical activity energy expenditure in boys with developmental coordination disorder: the role of peer relations in self-concept perceptions. *OTJR*, 28(1), 30-39.
- Poulsen, A.A., Ziviani, J.M., Cuskelly, M., & Smith, R. (2007). Boys with

- developmental coordination disorder: loneliness and team sports participation. *American Journal of Occupational Therapy*, 61, 451-462.
- Prentice, A. M. (1998). Body mass index standards for children. *BMJ*, 354, 1874-1875.
- Querne, L., Berquin, P., Vernier-Hauvette, M., Fall, S., Deltour, L. & Meyer, M. (2008). Dysfunction of the attentional brain network in children with developmental coordination disorder : A fMRI study. *Brain Research*, 1244, 89-102.
- Reilly, J., Dorosty, A. R., Ghomizadeh, N. M., Sherriff, A., Wells, J. C., & Ness, A. R. (2010). Comparison of waist circumference percentiles versus body mass index percentiles for diagnosis of obesity in a large cohort of children. *International Journal of Pediatric Obesity*, 5, 151-156.
- Rey-Lopez, J.P., Vicente-Rodriguez, G., Biosca, M., & Moreno, L.A. (2008). Sedentary behaviour and obesity development in children and adolescents. *Nutr Metab Cardiovasc Dis*, 18, 242-251.
- Rippe, J.M., & Hess, S. (1998). The role of physical activity in the prevention and management of obesity. *J Am Diet Assoc*, 2, 31-38.
- Ritchie, L.D. (2012). Less frequent eating predicts greater BMI and waist circumference in female adolescents. *Am J Clin Nutr*, 95(2), 290-296.
- Rivard, L. M., Missuina, C., Hanna, S. & Wishart, L. (2007). Understanding teacher's perceptions of the motor difficulties of children with developmental co-ordination disorder(DCD). *British Journal of Educational Psychology*, 77, 633-648.
- Rivilis, I., Hay, J., Cairney, J, Klentrou, P., Liu, J., & Faight, B. E. (2011). Physical activity and fitness in children with developmental coordination disorder: A systemic review. *Research in Developmental Disabilities*, 32, 894-910.

- Rivilis, I., Liu, J., Cairney, J., Hay, J. A., Klentrou, P., & Faught, B. E. (2012). A prospective cohort study comparing workload in children with and without developmental coordination disorder. *Research in Developmental Disabilities*, 33, 443-448.
- Roberts, K.C., Shields, M., Groh, M.D., Aziz, A., & Gilbert, J.A.. (2012). Overweight and obesity in children and adolescents: Results from the 2009 to 2011 Canadian Health Measures Survey. *Health Reports*, 23(3), 1-5.
- Rocandio, A. M., Ansotegui, L., & Arroyo, M. (2001). Comparison of dietary intake among overweight and non-overweight school children. *International Journal of Obesity*, 25, 1651-1655.
- Rodriguez-Artalejo, F., Garces, C., Gorgojo, L., Lopez, G.E., Martin-Moreno, J.M., Benavente, M., ... de Oya M. (2002). Dietary patterns among children aged 6-7 y in four Spanish cities with widely differing cardiovascular mortality. *European Journal of Clinical Nutrition*, 56, 141-149
- Roemmich, J.N., Clark, P.A., Mai, V., Berr, S.S., Weltman, A., Veldhuis, J.D., & Rogol, A.D. (1998). Alterations in growth and body composition during puberty: III. Influence of maturation, gender, body composition, fat distribution, aerobic fitness, and energy expenditure on nocturnal growth hormone release. *J Clin Endocrinol Metab*, 83, 1440–1447
- Rose, B., Larkin, D., & Berger, B.G. (1997). Coordination and gender influences on the perceived competences of children. *Adapted Physical Activity Quarterly*, 12, 210-221. Rose, B., Larkin, D., & Berger, B.G. (1998). The importance of motor

- coordination for children's motivational orientations in sport. *Adapted Physical Activity Quarterly*, 15, 316-327.
- Rowland, T. (1992). Trainability of the cardiorespiratory system during childhood. *Canadian Journal of Sport Sciences*, 17 (4), 259-263.
- Ruan, D., Chen, G., Kerre, E.E. & Wets G. Intelligent Data Mining: Techniques and Applications. Studies in Computational Intelligence Vol. 5 Springer 2005.
- Sallis, J. F., Buono, M. J., Roby, J. J., Micale, F. G., & Nelson, J. A. (1993). Seven-day recall and other physical activity self-reports in children and adolescents. *Medicine & Sports Science in Sports and Exercise*, 25(1), 99-108.
- Schott, N., Alof, V., Hultsch, D., & Meermann, D. (2007). Physical fitness in children with developmental coordination disorder. *Res Q Exer Sport*, 78(5), 438-450.
- Scott, W.D., & Dearing, E. (2012). A longitudinal study of self-efficacy and depressive symptoms in youth of a North American Plains tribe 1. *Development and Psychopathology*, 24(2), 607-622.
- Semiz, S., Ozgoren, E., & Sabir, N. (2007). Comparison of ultrasonographic and anthropometric methods to assess body fat in childhood obesity. *International Journal of Obesity*, 31, 53-58.
- Shomaker, L.B., Tanofsky-Kraff, M., Savastano, D.M., Kozlosky, M., Columbo, K.M., Wolkoff, L.E., ... Yanovski, J.A. (2010). Puberty and observed energy intake: boy, can they eat! *Am J Clin Nutr*, 92(1), 123-129.
- Siervogel, R.M., Demerath, E.W., Schubert, C., Remsberg, K.E., Chumlea, W.C., Sun, S., ... Towne, B. (2003). Puberty and body composition. *Horm Res*, 60, 36-45.
- Silman, A., Cairney, J., Hay, J., Klentrou, P., & Faught, B. E. (2011). Role of physical

- activity and perceived adequacy on peak aerobic power in children with developmental coordination disorder. *Human Movement Science*, 30, 672-681.
- Skinner, A.C., Steiner, M.J., & Perrin. (2010). Self-reported energy intake by age in overweight and health-weight children in NHANES, 2001-2008. *Pediatrics*, 130, e936-e942.
- Skinner, R.A. & Piek, J.P. (2001). Psychosocial implications of poor motor coordination in children and adolescents. *Human Movement Science*, 20, 73-94.
- Smith, C.P., Dunger, D.B., Williams, A.K.J., Taylor, A.M., Perry, L.A., Gale, E.A.M., ... Savage, M.O. (1989). Relationship between insulin, insulin-like growth factor I, and dehydroepiandrosterone sulfate concentrations during childhood, puberty, and adult life. *J Clin Endocrinol Metab*, 68, 932-937.
- Smyth, M. M., & Anderson, H. I. (2000). Coping with Clumsiness in the school playground: social and physical play in children with coordination impairments. *British Journal of Developmental Psychology*, 18(3), 389-413.
- Sonneville, K.R., Horton, N.J., Micali, N., Crosby, R.D., Swanson, S.A., Solmi, F., & Field, A.E. (2013). Longitudinal associations between binge eating and overeating and adverse outcomes among adolescents and young adults: doe loss of control matter? *JAMA Pediatr*, 167(2), 149-155.
- Speakman, J.R. & Selman, C. (2003). Physical activity and resting metabolic rate. *Proc Nutr Soc*, 62(3), 621-624.
- Spironello, C., Hay, J., Missiuna, C., Faught, B. E., & Cairney, J. (2009). Concurrent and construct validation of the short form of the Bruininks-Oseretsky Test of Motor Proficiency and the Movement-ABC when administered under field

- conditions: implications for screening. *Child: care, health, and development*, 36(4), 499-507.
- Stampfer, M. J., Hu, F. B., Manson, J. E., Rimm, E. B., & Willett, W. C. (2000). Primary Prevention of Coronary Heart Disease in Women through Diet and Lifestyle. *New England Journal of Medicine*, 343(1), 16–22.
- Starling, R.D., Matthews, D.E., Ades, P.A., & Poehlman, E.T. (1999). Assessment of physical activity in older individuals: a doubly labeled water study. *J Appl Physiol*, 86(6), 2090-2096.
- Staten, L.K., Taren, D.L., Howell, W.H., Tobar, M., Poehlman, E.T., Hill, A., ...Ritenbaugh, C. (2001). Validation of the Arizona Activity Frequency Questionnaire using doubly labeled water. *Med Sci Sports Exerc*, 33(11), 1959-1967.
- Statistics Canada. (2006). Table 051-0001 estimates of population, by age group and sex, Canada, provinces and territories, annual (persons).Statistics Canada. Available from http://cansim2.statcan.ca/cgiwin/cnsmcgi.pgm?&Lang=E&ArrayId=510001&Array_Pick=1&Detail=1&ResultTemplate=CII/CII&RootDir=CII/ Accessed December 2012.
- Stewart, K. J, Seemans, C., McFarland, L. D, Weinhofer, J. J, & Brown, C. S. (1999). Dietary fat and cholesterol intake in young children compared with recommended levels. *J Cardiopulmonary Rehabil*, 19, 112-117.
- Story, M.. Nutritional requirements during adolescence. In: McAnarney ER, Kreipe RE, Orr DE, Comerici GD, eds. Textbook of adolescent medicine. Philadelphia: W.B. Saunders, 1992:75-84.

- Sun, M., Gower, B.A., Bartolucci, A.A., Hunter, G.R., Figueroa-Colon, R., & Goran, M.I. (2001). A longitudinal study of resting energy expenditure relative to body composition during puberty in African American and white children. *Am J Clin Nutr*, 73, 308–315.
- Tanner, J.M., & Davies, P.S.W. (1985). Clinical longitudinal standards for height and height velocity for North American children. *J Pediatr* 107, 317–329.
- Tanner, J.M., & Whitehouse, R.H. (1976). The adolescent growth spurt of boys and girls of the Harpenden Growth Study. *Ann Hum Biol* 3, 109–126.
- Thompson, F.E., & Byers, T. (1994). Dietary assessment resource manual. *J Nutr*, 124(suppl), 2245S–317S.
- Tremblay, M.S., & Willms, J.D. (2000). Secular trends in the body mass index of Canadian children. *Canadian Medical Association Journal*, 163 (11), 1429-1433.
- Trumble-Waddell, J.E., Campbell, M.L., Armstrong, L.M., & Macpherson, B.D. (1998). Reliability and validity of the three-day estimated record of food intake provided by parents and caregivers of preschool children in dual-earner families. *Can J Diet Pract Res*, 59(2), 83-89.
- Tsai, M.R., Chang, Y.J., Lien, P.J., & Wong, Y. (2011). Survey on eating disorders related thoughts, behaviors and dietary intake in female junior high school students in Taiwan. *Asia Pac J Clin Nutr*, 20(2), 196-205.
- Tsang, W.W., Guo, X., Fong, S.S., Mak, K.K., & Pang, M.Y. (2012). Activity participation intensity is associated with skeletal development in pre-pubertal children with developmental coordination disorder. *Res Dev Disabil*, 33(6), 1898-1904.

- U.S. Census Bureau. (2006). National population estimates – characteristics. Available from <http://www.census.gov/popest/national/asrh/NC-EST2005-sa.html> Accessed December 2012.
- Vaivre-Douret, L. (2007). Troubles d'apprentissage non verbal: les dyspraxies developpementales. *Archives de Pediatre*, 14, 1341-1349.
- Vaivre-Douret, L., Lalanne, C., Ingster-Moati, I., Boddaert, N., Cabrol, D., Dufier, J., ... Falissard, B. (2011). Subtypes of developmental coordination disorder: Research on their nature and etiology. *Developmental Neuropsychology*, 36(5), 614-643.
- Val Abbassi. (1998). Growth and normal puberty. *Pediatrics*, 102(3), 507-511.
- Van Baak, M.A. (1999). Physical activity and energy balance. *Public Health Nutrition*, 2(3a), 335-339.
- Wang, Y. (2002). Is obesity associated with earlier sexual maturation? A comparison of the association in American boys vs girls. *Pediatrics*, 110(5), 903– 910.
- Wang, T. N., Tseng, M. H., Wilson, B. N., & Hu, F. C. (2009). Functional performance of children with developmental coordination disorder at home and at school. *Dev Med Child Neurol*, 51(10), 817-825.
- Ward, D. S., Evenson, K. R., Vaughn, A., Rodgers, A. B., & Troiano, R. P. (2005). Accelerometer use in physical activity: Best practices and research recommendations. *Medicine & Science in Sports & Exercise*, 37(11), 582-588.
- Welk, G., Differding, J., Thompson, R., Blair, S., Dziura, J., & Hart, P. (2000). The utility of the Digi-Walker step counter to assess daily physical activity patterns. *Medicine and Science in Sports and Exercise*, 32, S481-S488.
- Whitaker, R.C., Wright, J.A., Pepe, M.S. (1997). Predicting obesity in young adulthood from childhood and parental obesity. *N Engl J Med*, 337, 869-873.

- Williams, H. G., Pfeiffer, K. A., O'Neil, J. R., Dowda, M., McIver, K. L., Brown, W. H., & Pate, R. R. (2008). Motor skill performance and physical activity in preschool children. *Obesity*, 16, 1421-1426.
- Willett, W. (2001). Commentary: Dietary diaries versus food frequency questionnaires – a case of indigestible data. *Int J Epidemiol*, 30(20), 317-319.
- Willett, W.C., Sampson, L., Stampfer, M.J., Rosner, B., Bain, C., Witschi, J., ... Speizer, F.E. (1985). Reproducibility and validity of a semiquantitative food frequency questionnaire. *Am J Epidemiol*, 122(1), 51-65.
- World Health Organization (1992) *International Statistical Classification of Diseases and Related Health Problems, 10th edn, Vol. 1, ICD-10*. Geneva, WHO.
- World Health Organization. *Obesity: preventing and managing the global epidemic: report of a WHO consultation on obesity*: WHO: Geneva; 1998
- World Health Organization. *Global Recommendations on Physical Activity for Health*. Geneva, World Health Organization, 2010.
- Wrotniak, B. H., Epstein, L. H., Dorn, J. M., Jones, K. E., & Kondilis, V. A. (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics*, 118(6), 1758-1765.
- Wu, Q., Suzuki, M. (2006). Parental obesity and overweight affect the body-fat accumulation in the offspring: the possible effect of a high-fat diet through epigenetic inheritance. *Obesity Reviews*, 7(2), 201-208.
- Yu, C.W., Sung, R.Y.T., So, R., Lam, K., Nelson, E.A.S., Li, A.M.C., ... Lam, P.K.W. (2002). Energy expenditure and physical activity of obese children: cross-sectional study. *Hong Kong Med J*, 8, 313-317.

Zwicker, J. G., Missiuna, C., & Boyd, L. A. (2009). Neural correlates of developmental coordination disorder: A review of hypotheses. *Journal of Child Neurology*, 24(10), 1273-1280.

Zwicker, J. G., Missiuna, C., Harris, R. R., & Boyd, L. A. (2012). Developmental coordination disorder: A pilot diffusion tensor imaging study. *Pediatric Neurology*, 46, 162-167.

Appendices

Appendix A: Demographic Summary Table with Exclusion of Missing Data and

Outliers

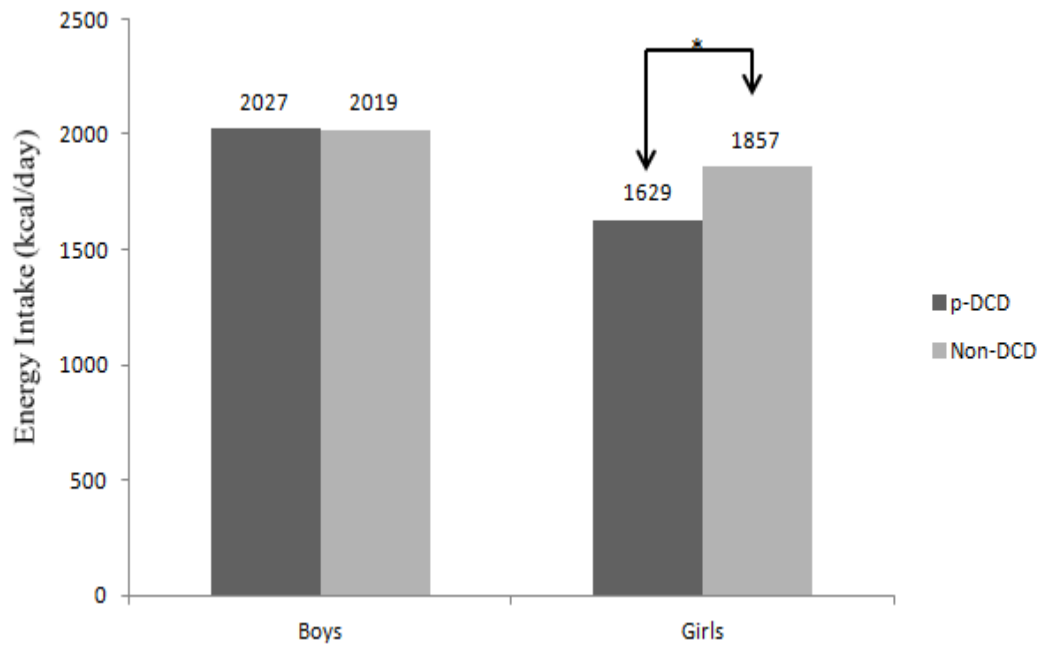
Table A1. Summary of results by p-DCD status in those included and excluded in terms of energy intake data (N=1935)

	p-DCD Included	Non-DCD Included	p-DCD Excluded	Non-DCD Excluded
N	115	1820	95	1587
Males (%)	35.7*	52.1	33.7*	52.1
Age (yrs, mean [SD])	12.4 [0.4]	12.4 [0.3]	12.4 [0.3]	12.4 [0.3]
BMI (kg/m ² [SD])	23.7 [5.1]*	19.8 [3.7]	24.1 [5.2]	19.8 [3.7]

*Note: comparison made between p-DCD and non-DCD. *Indicates a statistically significant difference (p<0.05).*

Appendix B: Additional Energy Intake Results

Figure B1. Median energy intake (kcal/day) in children with and without p-DCD according to gender (N=1695)



**Note: Significant difference between p-DCD and non-DCD among girls ($p=0.003$).*

Appendix C: Additional Logistic Regression Results

Table C1. Logistic regression analyses of p-DCD and energy intake on high waist circumference by gender

	N	p-DCD	Energy intake	χ^2
Boys				
Model 1	991	3.42 (1.86, 6.42)*		15.3
Model 2	858	3.16 (1.55, 6.45)*		10.6
Model 3	858	3.24 (1.56, 6.74)*	0.90 (0.77, 1.05)	16.0
Model 4	858	3.35 (1.57, 7.15)*	0.89 (0.76, 1.05)	77.8
Girls				
Model 1	938	6.46 (3.90, 10.72)*		59.7
Model 2	817	6.57 (3.76, 11.49)*		69.5
Model 3	817	6.32 (3.60, 11.07)*	0.78 (0.65, 0.94)*	73.3
Model 4	817	5.03 (2.80, 9.02)*	0.77 (0.64, 0.93)*	119.8

High WC (≥ 76.0 cm in boys and ≥ 76.2 cm in girls). OR (95% CI); EI transformed to EI/1027.1 for boys and EI/882.9 for girls to make the OR more interpretable. *Indicates statistically significant result ($p < 0.05$). χ^2 indicates likelihood ratio of the model for covariates.

Model 1: included p-DCD and residence.

Model 2: included Model 1 and physical inactivity.

Model 3: included Model 2 and EI.

Model 4: included Model 3 and maturity status.

Table C2. Logistic regression analyses of p-DCD and physical inactivity on overweight or obesity status by gender

	N	p-DCD	Physical inactivity	χ^2
Boys				
Model 1	991	4.01 (2.13, 7.58)*		19.4
Model 2	991	3.37 (1.76, 6.43)*	1.13 (1.05, 1.22)*	30.7
Model 3	858	3.24 (1.56, 6.74)*	1.12 (1.04, 1.21)*	16.0
Model 4	858	3.35 (1.57, 7.15)*	1.13 (1.05, 1.23)*	77.8
Girls				
Model 1	938	4.17 (2.56, 6.78)*		34.5
Model 2	938	4.09 (2.51, 6.66)*	1.05 (0.96, 1.14)	35.9
Model 3	817	4.74 (2.76, 8.13)*	1.06 (0.97, 1.16)	45.2
Model 4	817	3.16 (1.78, 5.61)*	1.09 (0.99, 1.19)	103.1

Overweight and obese ($BMI \geq 21.48$ kg/m² in boys and ≥ 22.02 kg/m² in girls). OR (95% CI); *Indicates statistically significant result ($p < 0.05$). χ^2 indicates likelihood ratio of the model for covariates.

Model 1: included p-DCD and residence.

Model 2: included Model 1 and physical inactivity.

Model 3: included Model 2 and EI

Model 4: included Model 4 and maturity status.

Appendix D: Descriptions of Studies Assessing the Association between energy intake and Body Mass

Skinner, Steiner, & Perrin (2012) examined the relationship between energy intake and body mass using two-day 24 hour recalls and BMI percentiles from the Centers for Disease Control and Prevention. They found that adolescents aged 12-14 years old who were either overweight or obese consumed less energy than those who were of healthy weight. In girls, for example, the mean energy intake among the healthy weight group was 1893 kcal/day vs. 1794, 1783, and 1484 kcal/day in the overweight, obese, and very obese groups, respectively. Although the difference was not as significant as in girls, a very similar trend was observed in boys. In boys, the mean energy intake among the healthy weight group was 2291 kcal/day vs. 2209, 2117, and 2024 kcal/day in the overweight, obese, and very obese groups, respectively. The author discussed that this finding may be a result of an increased energy intake which may have led to an early onset of obesity years before the date the study was conducted.

Rocandio, Ansotegui, & Arroyo (2001) examined the differences in energy intake between 32 overweight and non-overweight children aged 11 years old. Energy intake was estimated using a 7-day weighted diet record, in which a registered dietician trained the parents of the children for recording what the children consumed. Body weight status was measured using BMI percentiles (overweight cut-off was the 90th percentile). The researchers found that energy and carbohydrate intakes were significantly lower in the overweight group compared to the non-overweight group (2148 vs. 2302 kcal/day and 222 vs. 251 g/day, respectively). Intakes of fat and protein were very similar in both groups. Although a limitation to this study was a small sample size, the authors

concluded that the belief that overweight children consume more than normal weight children is not true, and that the positive energy balance leading to an overweight status is likely due to a low energy output (possibly from sedentary lifestyles).

Bandini, Must, Cyr, Goldberg, & Dietz (1999) studied the association between energy intake and obesity among 43 children aged 12-18 years old. energy intake was estimated from a 14-day food record, and a registered dietician trained participants how to keep their records. With the use of a financial incentive, the participants were required to further review their food records with research assistants several times to ensure accuracy. Total energy expenditure and obesity status were measured by doubly labeled water and BMI, respectively. The purpose of considering energy expenditure was to assess potential underreporting. The researchers found that both non-obese and obese groups underreported energy intake, but underreporting was much greater for the obese group. energy intake from high-calorie, low-nutrient-dense food was lower in the obese group. Based on the results of this study, the authors explain that there was no evidence to support the claim that obese adolescents eat more than non-obese adolescents.

Llunch, Herbeth, Mejean, & Siest (2000) sampled 290 girls with a mean age of 15.8 years old. They used a 3-day diet record and BMI to measure energy intake and weight status, respectively. The authors found a significant, weak negative correlation between energy intake and BMI ($r = -0.19$)

In another study, Tucker, Seljaas, & Hager (1997) measured energy intake and body fat percentage using the National Cancer Institute FFQ and the average of two skinfold equations. They found that energy intake from carbohydrates was negatively associated with adiposity among 253 children aged 10 years old.

Stewart, Seemans, McFarland, Weinhofer, & Brown (1999) used 24-hour diet records and skinfold thickness and BMI to measure energy intake and obesity, respectively. They sampled 468 children with a mean age of 9 years old. They found that fatter children consumed fewer calories than thinner children.

Garaulet, Martinez, Victoria, Perez-Llamas, Ortega, & Zamora (2000) studied the association between energy intake and overweight and obesity status in 331 adolescents aged 14-18 years old. Prospective 7-day food records and BMI were used to measure energy intake and obesity status, respectively. The overweight group under-reported energy consumption, and consumed less energy and carbohydrates than the normal weight group.

Eating frequency has positively associated with energy intake (Cutler, Glaeser, & Shapiro, 2003) so Ritchie (2012) attempted to investigate the relationship between an objective measure of eating frequency (3-day diet records) and adiposity (BMI and WC) in a 10-year cohort study involving 2379 girls aged 9-10 years old at baseline. This author found that a lower eating frequency predicted a greater gain in adiposity in the girls.

Similar results to the above study were found in a one-year non-randomized intervention study by Fabry, Hejda, Cerny, Osancova, Pechar, & Zvolankova (1966) involving 226 children aged 6-16 years old. In this study, there were three meal frequency groups non-randomly assigned: a reduced frequency (three times/day), an increased frequency (seven times/day), and a normal frequency (five times/day). Body fat was measured using skinfold thickness. The authors found that an increased eating frequency (seven or five times/day compared to 3 times/day) resulted in less weight gain

only in children 10-16 years old. The authors discuss that the potential mechanism for this finding could be a result of puberty differences.

Appendix E: Pooled Analyses

Table E1. Characteristics of participants aged 11-13 years old in the PHAST Study (2007) by p-DCD status (N=1975)

	p-DCD	Non-DCD	p-value
N	119	1856	
Males (%)	35.3	52.2	0.0003
Age (yrs, mean [SD])	12.4 [0.3]	12.4 [0.4]	0.823
Rural housing (%)^	28.6	36.4	0.086
BMI (BMI, mean [SD])^	23.7 [5.1]	19.8 [3.7]	<0.0001
PiA (score, mean [SD])^	8.3 [1.9]	7.4 [1.9]	<0.0001
APHV (yrs, mean [SD])^	-2.41 [0.48]	-2.29 [0.46]	0.019
EI (g/day, mean [SD])^	1909 [898]	2174 [967]	0.009
EI (g/day, median [Q1-Q3])^	1673 [1344-2321]	1949 [1509-2661]	0.005

PiA physical inactivity; EI energy intake; BMI body mass index; APHV age-to-peak height velocity. ^Indicates sample size change.

Table E2. Pearson correlation matrix of MP, BMI, WC, PiA, EI, and APHV

	MP	BMI	WC	PiA	EI	APHV
MP		-0.320 <0.0001 1935	-0.330 <0.0001 1938	-0.069 0.002 1935	0.087 0.0003 1695	0.0135 0.558 1899
BMI			0.906 <0.0001 1934	0.083 0.0003 1924	-0.115 <0.0001 1682	0.005 0.812 1899
WC				0.101 <0.0001 1926	-0.101 <0.0001 1684	0.077 0.001 1898
PiA					0.058 0.017 1683	0.058 0.017 1683
EI						-0.036 0.138 1672

Note: numbers are arranged as such: r-value, p-value, sample size. MP motor proficiency; BMI body mass index; WC waist circumference, PiA physical inactivity, EI energy intake; APHV age-to-peak height velocity.

Table E3. Logistic regression analyses of p-DCD and energy intake on overweight or obesity status in all children

	N	p-DCD	Energy intake	χ^2
Model 1	1929	4.11 (2.79, 6.04)*		54.4
Model 2	1687	4.62 (3.02, 7.09)*		60.4
Model 3	1675	4.26 (2.76, 6.56)*	0.87 (0.77, 0.98)*	69.3
Model 4	1675	4.27 (2.76, 6.62)*	0.87 (0.77, 0.98)*	69.5

*Overweight or obese ($BMI \geq 21.48 \text{ kg/m}^2$ in boys and $\geq 22.02 \text{ kg/m}^2$ in girls). OR (95% CI); EI transformed to EI/964.8 to make the OR more interpretable. *Indicates statistically significant result ($p < 0.05$). χ^2 indicates likelihood ratio of the model for covariates.*

Model 1: included p-DCD, gender, and residence. There was no significant p-DCD X gender interaction ($p = 0.900$).

Model 2: included Model 1 and physical inactivity.

Model 3: included Model 2 and EI.

Model 4: included Model 3 and maturity status. There was a significant gender X maturity status interaction ($\chi^2=119.8$, $p < 0.0001$).